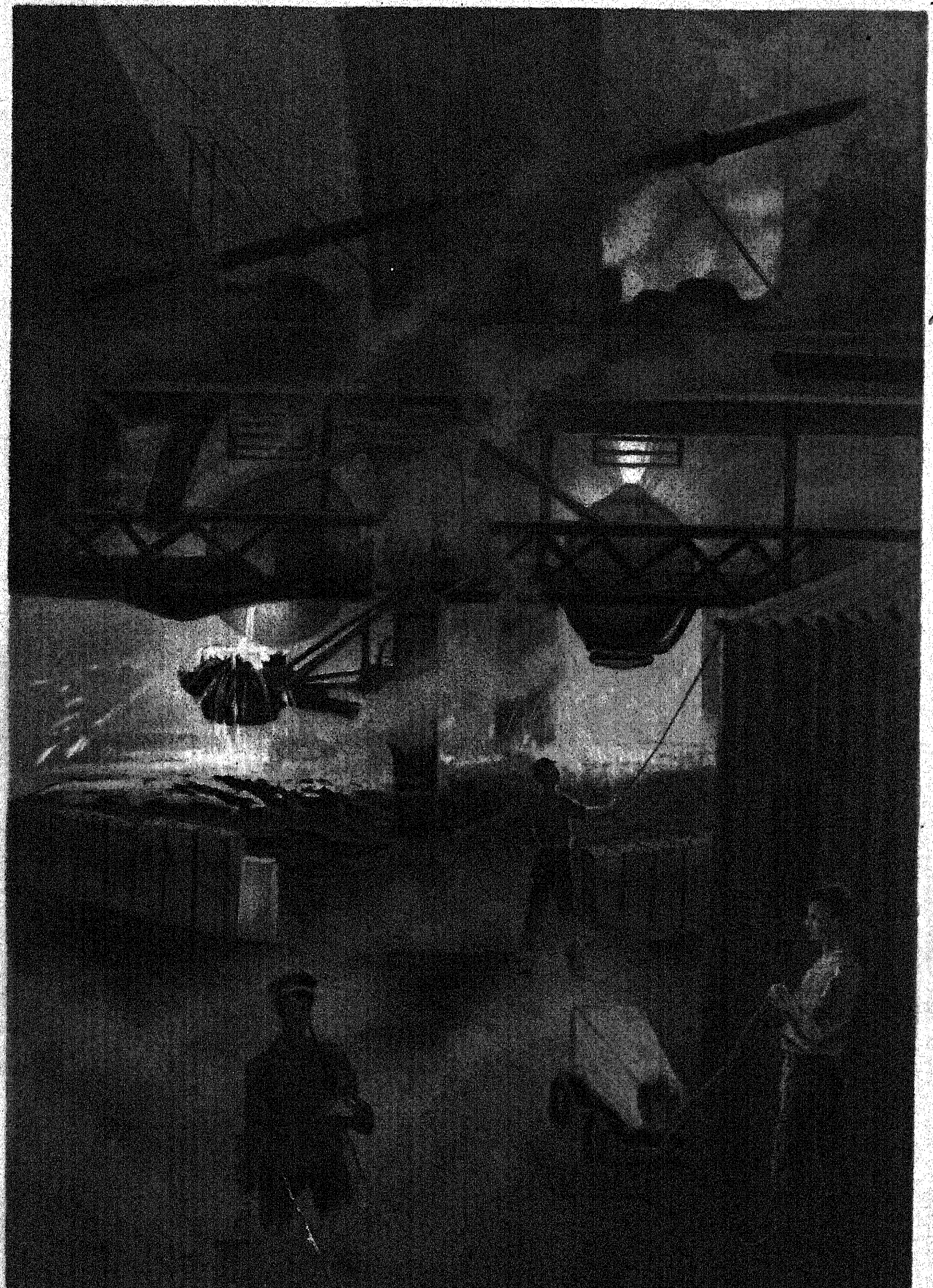

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THE

NEW TECHNICAL EDUCATOR

An Encyclopædia

OF

TECHNICAL EDUCATION

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CASSELL'S NEW TECHNICAL EDUCATOR.

TECHNICAL EDUCATION:

"WHAT IT IS."

By Henry Cunynghame.

The object of general education is to train up good, wise, and useful men, sound in mind and in body. The object of Technical Education is to make good industrial workmen.

1. If we inquire what are the qualities which go to make up a good workman, whether he be the manager of a business, or an operative, we find they may be grouped under two heads—moral and technical. The former are, perhaps, the more important to success. But these do not come within the scope of our present inquiry. The technical qualities are five in number :—

(1) Inventive or constructive power.
(2) Artistic feeling.
(3) Knowledge of the principles of science and art.
(4) Knowledge how to apply these principles practically.
(5) Hand, or manipulative, skill.

2. Of these, the first two come mostly by nature, but they can be immensely improved by training. Englishmen possess them both to a remarkable degree, for the people of Great Britain are very inventive, and have naturally considerable artistic gifts, especially in their taste for colour.

The power of invention largely depends on seeing similarities and analogies in things which at first appear widely different. Thus the hollow stem of a bamboo, which nature uses for lightness and strength, might suggest the proper form for an iron pillar. The inventive faculty is in constant exercise in all the more agreeable forms of industrial work. The mechanic has to invent methods of chucking his work in the lathe, and numberless artifices for shaping special tools.

Invention and art are from above, and but little of them can be taught. They come like the wind, no one knows whence, but so widely are they spread that there are few children who have not the germs of either one or the other, which germs, when encouraged, will yield good fruit.

3. If, on the one hand, art and invention are natural gifts, on the other scientific knowledge is the reward of industry. The poet may be born, but the orator is made, and so far as knowledge is concerned, resolute perseverance generally counts for more than the most brilliant gifts. The German nation is an excellent example of this. They have not displayed of late years any very shining ability in art, poetry, literature, or mechanics ; and yet by sheer work they have acquired a first-rate place in almost all branches of knowledge and industry.

The use of a knowledge of principles, as compared with the mere routine of the workshop, cannot be overrated. It is this which distinguishes the true mechanic from the mere factory hand. It is this that makes work a pleasure instead of a drudgery, and it is only by knowledge of principles that inventions can be made. As one example, consider how few bakers know the true reason why yeast is put into bread. Yeast consists of a multitude of microbes. When placed in the wet dough these microbes grow, and in their growth they develop quantities of gas. This gas causes the bread to become spongy, that is, to "rise." When the bread is baked the microbes are killed, but the bread remains full of bubbles of air. Once these principles are clear, it becomes easy to suggest different modes of producing the same effect. One inventor pumped air into the wet dough, and aërated bread was the result. Another mixed in the dough a powder consisting of two chemicals, which when united effervesced, and thus invented baking-powder. Another proposed to add carbonate of soda to the flour, and hydrochloric acid to the water used to moisten it. Carbonic acid gas was thus generated, which caused the bread to rise, and also produced common salt to season it. None of these devices, however, could have been invented except by men who understood the principles of baking as contrasted with the mere practice of it.

The working men of England are at present woefully behind the Germans in knowledge; nay, they are so unwise as to despise it.

Peculiar advantages, such as the absence of war, the discovery of coal, the central position of Great Britain and the energy of her inhabitants, have hitherto given her the lead over the rest of the world. But there are already signs of a falling off in many trades. The cotton spinning trade is gradually declining, and in dyeing the Germans are far in advance of us. If we are to maintain our commercial supremacy, it can only be by making ourselves acquainted with new processes, and marching with the times.

4. But it is not enough to know scientific principles—we must know how to apply them. The more a man learns, the more is he surprised how wonderfully little knowledge is required in any profession, if only he knows how to use it. Some of our greatest engineers knew no more than arithmetic, geometry, and the main principles of mechanics. For practical purposes, therefore, it is not necessary to know much, provided it is known thoroughly.

All who are well acquainted with boys know that there are some who are always asking questions, and never pondering over the answer, but that there is also another slower, but (to their mothers and female relations) much more tiresome, class, who are never content with the answer, and who always go on till they get to the "Don't know" stage. When you meet such a boy or man, help him, for here you have got an inventor. In schools, as at present taught, repeated inspection has convinced me that three-quarters of the knowledge imparted there is never digested, and hence is worse than useless. This is all due to pushing the learners on too fast in order to prepare for some examination.

5. The last of the qualities above enumerated is hand-skill. This is partly natural, partly acquired, but if taken early almost all children can be educated to it. The making of small paper toys and models is a very useful practice, and I remember hearing Mr. Nasmyth say, that all children ought to play at "Spilikins."

The importance of hand-skill is not to be compared with that of head-skill, for in these days almost all accurate handwork is done by means of some sort of tools. Accurate eye-judgment is, however, most useful, and can be trained to an extraordinary degree. In delicacy of hand women generally greatly surpass men. On the other hand, the nervous and tactile organisation of men is naturally more delicate than that of women.

6. Having thus briefly reviewed the qualities which it is desirable that workmen should possess, and indicated those which are principally susceptible of improvement by training, it becomes necessary to inquire how that training can best be acquired, and why technical education is more necessary at the present time than it has been in the past.

In olden days trades were chiefly in the hands of privileged bodies of men, and the right to practise them could only be obtained after a long and wearisome apprenticeship. The old apprenticeship system has, however, broken down, and there appears little probability of its restoration. The causes of this are partly the spread of trade secrets by means of printing, partly the disorganisation of our social life by means of railways, partly increased facilities for emigration, and partly the introduction of machinery, and the consequent development of the factory system.

The result has been bad. In spite of our great improvements in knowledge and in invention, the workman has not kept pace with the time.

Boys are far too soon liberated from the healthy control of their parents or foremen, and are far too anxious to earn immediate wages, rather than to look to more distant but higher remuneration.

If this movement continues, the effect will be to drive from England all the trades requiring high knowledge or delicate skill, and to leave us in possession only of those which are conducted by a highly educated body of foremen or engineers, directing labour of a dull and unintelligent order.

This would be deeply regrettable, and would also infallibly end in the lowering of wages. It is therefore highly necessary, not only for the general prospects of manufacture in Great Britain, but also for the prospects of our workmen, that some effort should be made to replace or supplement the apprenticeship system by means of technical education.

7. An attentive perusal of the above remarks will have prepared us to see that there are really three stages or degrees in technical education in any craft or art. First there is the purely theoretical stage; secondly, the semi-theoretic stage, in which the application is taught of theoretical truth to practice; and lastly there is the actual instruction in the art itself. An example may make this more clear. Suppose that a man's business were to make baths out of zinc in various shapes and forms and of sizes which constantly varied. He ought first to be a bit of a geometrician. He ought to be able to draw not only a circle of any size, but an ellipse, or, if need be, a parabola. Then he should be able to divide up a line into any number of parts, to draw an angle of any size, to draw a hexagon, a pentagon, or a square in a circle, to inscribe a circle in any

triangle, to calculate the length of the circumference of a circle, to calculate the cubic content of any figure, and estimate how much liquid it would hold. If he could do all this well, he would possess a very fair knowledge of geometry. This would be the first stage of his learning. But it would not be enough, for he must next know how to apply his knowledge. For instance, he would have to know the sizes in which baths are generally made, what is the shape of them that is most convenient, how cisterns should be constructed, how the joints should be made, and other similar matters. Here, then, he is in the second stage; he is now in "geometry applied to bath-making." Notice that as yet he may not have handled a tool, he would be a mere designer or architect of baths or cisterns; but when he takes his shears and bitt in hand and proceeds to carry out his theories he then becomes a workman. The first question that arises is, which of these ought to come first? For a man of very high education probably they should be taken in the order given above; but in instructing workmen it is best to take them in the inverse order. Thus, for instance, suppose you had the task of instructing a class of intelligent workmen how to make electric bells. You might, if you chose, begin with theoretical electricity and work downwards, but I have generally found it best to make a bell first, before the class, and then to work backwards. "Here is a bell: you see its parts, the gong, clapper, armature, magnet, wire, terminals, and stand. I turn on the electricity. The bell rings. Why does it ring?—Because the magnet attracts the armature. Why is this?—Because the electricity makes it magnetic. Why does it do so?" Thus by reversing the process, by proceeding in what is called the analytic method, instead of the synthetic, you will interest your class; whereas if you begin with the theory, the application of which they cannot see for a long time, you will weary them. Besides this, if they work backwards, they will see what is important, and on what points to concentrate their attention. The principle of this plan may be explained by saying generally that you should by a practical example first show the need of the investigation you are going to make and then gradually pursue it. When you have done, you might then proceed to illustrate it further thus:—Suppose we have a bell, could we not be content to see it ring without hearing the sound; instead of a clapper, to put a little index finger and watch it? Could we not even signal in such a manner by giving one or more taps? Could we not then make the magnets smaller, as the needle is so light, and thus do with less electricity? Let us try—let us make such a machine; we do so, and find that we have got the electric telegraph. But further, if we fix a pen to the clapper and modify our arrangements, we get the printing telegraph; and more wonderful still, if we make the clapper out of a bit of sheet iron and screw it down tight, we can actually transmit speech, and we have got the telephone.

These considerations show us that in technical education we should always endeavour to observe two rules, viz., to proceed from the known to the unknown, and so far as possible to show the dependence of what is taught upon wide general principles.

8. Learning of all kinds may be pursued from one of two motives, either from the pleasure it gives and its ennobling effect, or else as a means of gaining money. In the very materialistic age in which we live, when each successive year shows a decreasing desire for ideals, and an increasing desire of all classes for comforts and luxuries, when philanthropy, legislation, and politics are directed principally to increase our material welfare, when in fact the age is almost wholly dominated by epicurean philosophy, it is not to be expected that the working classes will escape these tendencies. On the contrary, materialism is almost the sole end of the socialistic or democratic movements of the day. Hence, then, it will be found in general in technical schools that those branches of study are most pursued which end in improved wages. This, though it may be regrettable, is to a great extent inevitable, and is not nearly as great an evil as at first sight appears. The best commencement for a young workman is a thorough understanding of the principles of his own trade. If ever he is to rise to higher things, it will not be by passing his own trade over, but through it, and by means of it. The fortunate man whose lot lies neither in being a mere quill-driver on the one hand, nor a mere factory hand on the other, into whose life a little invention or art can enter, whether it be the laying out of a garden, the decoration of a room, the planning and laying on of gas and water, or any other trade that involves responsibility and thought, is surrounded with the mysteries of nature. They hem him in on all sides, and he can make no one step forward in any detail of his trade without having the opportunity of self-culture.

He is not condemned like the lawyer to master the intricacies of Acts of Parliament made in ignorance one day and altered in ignorance on the morrow, or like the banker or tradesman to watch as if for his life the fluctuations of arbitrary market prices; his study is the laws of nature, of physics, of chemistry, as applied in the service of man; and if he will work, it is almost impossible for him to

improve his wages without also improving his mind. Hence, then, it is a healthy sign in technical schools when the men are zealous in studying their own trades; and though perhaps in Manchester they carry this zeal to an excess, yet elsewhere it has been found that every technical school which has been set up possesses a fair share of students who love knowledge for its own sake.

9. It remains only to add a few words upon the relation of technical schools to art. The art teaching of this country, which has been established among us for nearly half a century, has upon the whole been productive of great benefit, but our design is still very imperfect. Much—very much has been done in pottery, and much in fabrics and wall papers; a few really beautiful patterns are to be seen in almost every shop; but our silver work, our metal work, and our glass are, as a rule, beneath contempt from an artistic point of view, and our furniture is very poor. An especially hideous description of art seems to pervade all our cast-work whether in iron or brass; knockers, door-knobs, lamps, balustrades, chandeliers, gas brackets, tea and coffee pots, exhibit a wild jumble of Egyptian, Assyrian, Gothic, Greek, or Rococo, put together without taste or judgment. It is perhaps not quite so bad as the terrible specimens of a like nature which come from America, but is hopelessly inferior to similar art in France.

The great work of our art classes in technical schools should be to remedy these defects; not to aim at high art as they almost invariably do, but to get out simple household articles of beautiful and ingenious patterns. A single glance at a collection of door-knockers from Pompeii will convince anyone who is sceptical on this head. We must pitilessly laugh down our bad picture-painters, remembering that a good painter is as rare as a good poet, and that a bad picture ought no more to be tolerated than a stupid poem. Yet the same student, who would blush to read his silly verses, will display with the pride of ignorance a vulgar daub in oil—aye, and get a medal for doing it, not because it is good, but because a prize must be given to somebody to satisfy our senseless system of rewarding people for doing what they ought to be dissuaded from attempting.

So far then as art is concerned, a technical school should confine its attention to industrial art, leaving the future Rembrandts and Titians to study in establishments more suited to their aspirations.

10. In conclusion, it should not be forgotten that we owe a duty to our girls as well as to our young men. So long as it is the custom of our race (and it has lasted long) that the man should be the principal bread-winner, and that at least after marriage a woman's chief care should be the household and children, so long it will be far more important that the men should be technically educated than the women. Women are not found to desire to study most of the trades, with the exception of art design, where their taste and feeling are of the highest value.

But it has hitherto been found practicable and desirable to open to them all the men's classes without exception, and mixed bodies of students work exceedingly well in practice. On the other hand, there are certain classes, such as those for dressmaking, dress-fitting, millinery and cooking, which it is usual to restrict to women, and in our towns it has hitherto been very disappointing to find how few avail themselves of these advantages. Speaking generally, it is probably almost impossible to find over the whole world women so completely ignorant of cookery and household management as the English, and so thoroughly averse to being taught. To tell a woman of the upper classes that she does not know how to cook is regarded as a compliment; by the working classes it is regarded as an insult. The one is proud of her ignorance, the other imagines that a mutton chop fried in a frying-pan till it is as hard as a piece of wood is the highest effort of culinary skill. There are but two remedies for this. The one that the upper classes should set the fashion in better domestic knowledge, and then the others will imitate them; the other would be that every young man should take lessons in cookery, and then the young woman would have to follow. The amount of good food that is rejected or wasted in our large towns is lamentable, and not the least benefit which technical education would afford would be the better instruction of our women in domestic management.

11. In the present days great efforts are being made in England to encourage the formation of Technical Institutes. Three or four new ones of large size have been established in London, and there are now few large towns which do not contain some kind of Technical School. But it is of no use that these schools should be founded if those for whom they are intended do not take advantage of them. It is the duty of parents to see that their sons do so, and it is no less the interest than the duty of employers to afford facilities to their apprentices to study in the evening. When one reflects how certain and large an increase of wages results from technical study, and how speedily those who pursue it rise in their trades, one can only be astonished at the folly and apathy of those who, for want of a little self-denial, throw away such solid and permanent advantages.

STEEL AND IRON.—I.

By William Henry Greenwood,
F.C.S., M.Inst.C.E., M.I.M.E., Assoc. Royal School of Mines.

IRON AND STEEL.

Archæologists agree in placing the Iron Age as more recent than the Bronze, although the metallurgy of iron, necessary for the production of malleable iron direct from the ore, is one of the simplest known, since iron ores such as the red or brown hæmatite, when heated in small quantities for a few hours in a charcoal wind-furnace, the ore being at the same time well embedded in the fuel, are more or less completely reduced, and yield a product which can be forged or hammered into a bar of malleable steely iron; while to produce bronze castings probably required a knowledge of the smelting of copper and of tin, besides an acquaintance with the art of moulding.

Malleable iron is, however, of great antiquity, and was the product of the earlier forges, being known long before cast-iron was produced. The Hindoos would appear to have employed the direct methods for producing malleable iron or steel as above mentioned from very early dates; but it is uncertain whether the Britons, prior to Cæsar's invasion, knew the uses of iron or the methods of its reduction. Although the malleable product was known thus early, the production of pig-iron would appear to date back only about 350 years.

Until the end of the sixteenth century wood was the only fuel used in iron-works; and it was not until 1733 that Abraham Darby, of Colebrookdale, successfully used coke in the blast-furnace. In 1740 the production of cast-steel was introduced into Sheffield; and in 1784 Henry Cort is accredited with having introduced the puddling furnace and the use of grooved rolls for the rolling of the metal. These dates would appear to mark the commencement of the rapid growth, and the vast series of improvements which have characterised the progress of the iron industries during the past century, culminating in the introduction of the Bessemer process in 1855 (*see* coloured plate), of the Siemens or Open-Hearth Steel manufacture in 1866, and of the Thomas and Gilchrist or Basic process in 1878. At the same time blast-furnace practice has been improved so that 2,000 tons of metal can be obtained per week from a single furnace; whilst single rolling-mills now turn out upwards of 4,000 tons of steel rails per week.

The study of the smelting of iron ores, and the treatment of iron and steel, forms one of the largest and most important branches of metallurgical science. It also presents a remarkable contrast to all other branches of the smelter's art, since there are only the oxides of iron, or such other combinations of the metal as are reducible to oxides by heat alone, that are available for the production of the commercial varieties of iron; whilst most of the other metals employed in the arts can be obtained from minerals varying much, both in the nature of their chemical composition, and in their richness of metal. Further, most of the common metals can be reduced from their ores by processes differing widely from one another; but *with iron the reducing agent is always either carbon or carbon monoxide*, and the product of the smelting operation is always iron combined with more or less of such other elements as carbon, silicon, sulphur, phosphorus, manganese, etc., which go to form pig-iron, malleable iron, and steel.

The chemistry of the pure metal and of its numerous salts will be best studied in the chemical laboratory, and thus only such compounds of iron as will present themselves during smelting operations, or in special laboratory operations connected with the metallurgy of iron, will be considered in these lessons.

Pure metallic iron is a body difficult of preparation, especially in the compact state, except by purely chemical methods, and is, moreover, a substance devoid of practical commercial importance; but in combination with variable although small proportions of *carbon*, and the other metallic and non-metallic elements just named, it constitutes the various commercial products known as pig-iron, steel, and malleable iron.

Pure iron is prepared by the electrolysis of ferrous chloride ($FeCl_2$), or by the reduction either of ferric oxide (Fe_2O_3) or ferrous chloride, by heating either of them to redness in a tube through which a current of hydrogen gas is passed; or in a nearly pure state iron can be obtained by the fusion, under a layer of glass free from metallic oxides, of fine iron-wire or iron-filings, with artificially-prepared magnetic oxide of iron. Iron as prepared by the last method is a metal varying in colour from bluish grey to silver whiteness according to the state of its aggregation; as reduced from ferric oxide by hydrogen at a low red heat, it forms a grey powder or spongy metal which, immediately it is exposed to the air, absorbs oxygen with such avidity as to cause the spontaneous ignition of the metal with the reproduction of ferric oxide. Electro-deposited iron absorbs or *occludes* hydrogen to the extent of from seventeen to twenty times its own volume; and it appears probable, as will be subsequently noted, that the combinations of iron with carbon, such as cast-iron and steel, also possess, when in their fused state, the power of occluding certain gases, which are to a certain

extent again liberated as the metal cools and solidifies. Pure iron is one of the best conductors of electricity, but this property is rapidly impaired as the iron becomes less pure. It can be magnetised to a very high degree, but rapidly loses its magnetism. Pure iron is softer than the commercial varieties of malleable iron, and has a specific gravity of 7·87. Its fusing point does not appear to have been accurately determined, for whilst Pouillet estimates it at from 1500° C. to 1600° C. (2732° Fahr. to 2912° Fahr.), Scheerer gives it as 2100° C. (3812° F.); but the presence of small quantities of carbon in combination with the metal rapidly lowers the fusing point.

Iron is not oxidised by exposure to dry air at ordinary temperatures (except when the iron is in the pyrophoric or spongy state already described). It is also unaffected by perfectly pure water in which air, free oxygen, or carbon dioxide is absent; but if exposed to a moist atmosphere, then the oxidation commonly known as *rusting* rapidly proceeds, especially if carbon dioxide be also present, as is usual, in the atmosphere. The presence of carbon dioxide appears essential to the oxidation of the iron by moisture, since the metal may be kept bright for almost any length of time in pure lime-water, or in a solution of soda. The hydrated ferric oxide, or rust, is also electronegative with respect to the metallic iron upon which it is formed, and the electrical condition thus resulting still further promotes the affinity of the metal for oxygen; and the corrosion of the iron under such conditions proceeds rapidly, even to the extent of enabling the iron slowly to decompose water with the evolution of hydrogen at ordinary temperatures. Water holding carbon dioxide in solution, even though free oxygen may be absent, rapidly attacks and oxidises metallic iron. Iron, when heated to redness in contact with air or oxygen, is rapidly oxidised, with the production of a black scaly oxide readily detachable from the surface of the iron. This oxide constitutes, on the large scale, the *hammer-scale* or *hammer-slag* of the forge. The scale formed in the forge, however, is never uniform in either composition or in physical characters, but consists of an outer layer which is strongly magnetic, almost metallic in lustre, brittle, fusible only at the highest temperatures, more highly oxidised and somewhat redder in colour than the inner layers, which are less lustrous, spongy, tougher, and less magnetic than the outer surface.

The *hammer-scale* or *hammer-slag* contains, besides magnetic oxide (Fe_3O_4), a variable excess of ferric oxide (Fe_2O_3), and hence the varying physical qualities just mentioned. Iron at a red heat also decomposes the vapour of water, with the liberation of hydrogen, and oxidation of the iron to the state of magnetic oxide.

Hydrochloric acid attacks metallic iron with the formation of ferrous chloride ($FeCl_2$) and the liberation of free hydrogen. Concentrated sulphuric acid (H_2SO_4) also attacks the metal, with the liberation of *sulphur dioxide* (SO_2), whilst ferrous sulphate ($FeSO_4$) remains in solution; but if the diluted acid be employed, then *hydrogen* is liberated, and ferrous sulphate remains in solution as before. The action of nitric acid upon iron, at the ordinary temperature, varies with the degree of concentration of the acid. Thus, while ordinary nitric acid attacks iron vigorously with the evolution of nitrous fumes in abundance, the dilute acid dissolves the metal without any sensible evolution of gas, with the formation of ferrous nitrate ($Fe2NO_3$) and ammonium nitrate (NH_4NO_3); thus $10(HNO_3) + 4Fe = 4(Fe2NO_3) + NH_4NO_2 + 3H_2O$. Strong-fuming nitric acid is without action upon the metal, a bright surface of which may be introduced into the cold concentrated acid without inducing any chemical decomposition, the surface of the metal assuming on immersion a dull whitish appearance, without any further action, the metal having then assumed what is known as the *passive condition*. The atomic weight of iron is 56, and its chemical symbol is Fe.

Iron and Oxygen.—Iron combines with oxygen in several proportions, of which the most important are *ferrous oxide* (FeO), *ferric oxide* (Fe_2O_3), and the combination of these two, constituting *magnetic oxide* (Fe_3O_4). The first-named is a very unstable compound obtained, according to Debray, as a black non-magnetic body, when steam and hydrogen in certain proportions are passed over heated ferric oxide.

Ferrous oxide, both in its anhydrous and hydrated forms, is a very unstable body, rapidly passing to a higher state of oxidation by exposure to the atmosphere. It is, however, a powerful base, and in combination with silica it enters largely into the composition of the various *slags, cinders,* etc., produced in the metallurgical treatment of iron; and by its combination with acids produces an important series of salts known as ferrous salts, which decompose on exposure to the atmosphere with the production of basic salts of the ferric oxide. Of ferrous salts, the most important to the metallurgist besides the silicates are the carbonate and the sulphate; of these the carbonate occurs anhydrous and crystallised in *spathic ore* or *siderite,* and amorphous, along with clay, lime, etc., in the various clay ironstones.

Ferric oxide (Fe_2O_3) is a very stable and practically fixed oxide of iron, decomposable,

however, at a white heat, with the liberation of oxygen and the production of the magnetic oxide ($3Fe_2O_3 = 2Fe_3O_4 + O$). Ferric oxide is produced when ferrous sulphate is strongly heated, the salt suffering decomposition with the elimination of sulphurous anhydride (SO_2) and sulphuric anhydride (SO_3), whilst a bright red pulverulent powder, forming the "*rouge*" or "*colcothar*" of commerce, is obtained, which has the composition of ferric oxide. This oxide, generally known as the red oxide of iron, occurs largely in such minerals and iron ores as hæmatite, iron-glance, specular iron, and micaceous iron ore; and in its hydrated condition ($Fe_2H_6O_6$) it occurs in the minerals brown hæmatite, limonite, and göthite. Ferric oxide is *decomposed with the reduction of metallic iron by heating it in a current of carbon monoxide* (CO), *of hydrogen, of ammonia* (NH_3), *or of cyanogen* (CN), *or by heating it along with carbon.*

The magnetic oxide (Fe_3O_4) has already been referred to in connection with iron-rust. It occurs native also as the black lustrous magnetic mineral known as *magnetite;* and it is also obtained when ferrous carbonate ($FeCO_3$) is decomposed at a red heat in the absence of air or oxygen; thus $3(FeCO_3) = Fe_3O_4 + 2CO_2 + CO$.

Iron and Carbon.—Although iron does not combine with carbon at ordinary temperatures, yet their union, when brought into contact at or above a red heat, may be readily effected, with the formation of compounds less highly carburised than pig-iron. Thus, by exposing malleable iron for some days to a temperature at or above a red heat, say 1000° C. to 1200° C. (1832° Fahr. to 2192° Fahr.), to the action of carbon in coarse powder, as in the ordinary manufacture of *blister* or *cement steel* by the process of cementation, it is found that a union of the carbon and iron gradually takes place, the iron bars becoming more highly carburised than the original metal. The carburisation in this case proceeds from the surface towards the middle of the bar, and penetrates farther into the bar the longer the temperature and contact with charcoal are maintained.

Case-hardening, again, is another example of the superficial carburisation of wrought-iron articles, by heating them to redness for a short time, in contact with leather, horn, or other highly carbonaceous compound. Cyanogen vapours and other cyanogen compounds, like potassium ferrocyanide (yellow prussiate of potash), $K_8(C_3N_3)_4Fe_2 + 6H_2O$, are decomposed by heated iron, with the carburisation of the iron, as in the case-hardening of small articles on the smith's hearth, which is done by sprinkling the last-named salt on the surface of the heated metal. At more elevated temperatures, such as those attained in the blast-furnace, carbon monoxide (CO), coal-gas, volatile hydro-carbons, cyanides, etc., are decomposed by metallic iron, with the carburisation of the latter; and again, the production of cast-steel by the crucible process is an example of the direct union of carbon and malleable iron, at the more elevated temperature required to melt steel.

Upon the degree of carburisation of iron, modified by the presence of other elements, like sulphur, phosphorus, silicon, and manganese, largely depends its commercial classification as cast-iron, steel, or malleable iron, with the widely different qualities possessed by these bodies; in the first-named the carbon may exist to the extent of nearly 5 per cent., while in mild steel the carbon need not to exceed 0·1 per cent. In cast- or pig- iron, in malleable iron, and also in steel, the carbon, although differing largely in amount, is always present in two conditions. In pig-iron one portion of the carbon exists as mechanically diffused crystalline scaly graphite, distributed with more or less regularity throughout the mass; and this carbon can be separated by purely mechanical means from the finely divided metal. Another portion of the total carbon is either *dissolved* in the metal, or otherwise it exists in a state of chemical combination with the iron, and is thus incapable of being separated from the iron by purely mechanical methods.

The action of acids upon pig-iron varies with the state in which the carbon exists in the pig; thus, when the metal is dissolved in hydrochloric acid, any *combined* or *dissolved carbon* unites with the hydrogen of the acid to the formation of gaseous and liquid hydrocarbons, at the same time the *graphite* or *uncombined carbon* remains along with the silica, as an insoluble residue; hence, when grey cast-iron is thus treated with hydrochloric acid, a large proportion of the carbon remains as graphite in the insoluble residue, whilst if white iron be similarly treated, only a small proportion of its carbon remains in the insoluble residue, the greater portion having combined with hydrogen, as above mentioned, and escaped in the gaseous form during the solution.

In *grey iron* the carbon exists almost wholly as graphite, which can be detached from the crystals of iron, and separated therefrom by the mechanical operation of sifting; but in *white iron*, such as *speigeleisen*, the carbon exists almost wholly in the combined or dissolved state, only a small quantity existing as graphite; while in *mottled iron* the proportions of combined and graphitic carbon are more nearly in equality. Molten cast-iron can hold an amount of carbon in solution, which, if the metal be allowed to cool slowly, will separate as graphite

or *kish*, while if the same metal be suddenly cooled the greater portion of such carbon may be retained in combination with the iron. In steel also, as will be more fully described later on, the carbon, although it is present in much smaller proportion than it is in pig-iron, still appears to exist under two conditions, often now described as *hardening* and *non-hardening* carbon respectively, the ratio of the one to the other in this case being influenced by the proportions of foreign metals in the steel, and also by the physical treatment to which the metal has been submitted.

Iron and Sulphur.—These elements by their union yield a considerable number of sulphides of iron; and they directly combine when a mixture of the two is heated to redness, the combination being attended with a considerable further evolution of heat; and according to the proportions of the elements present, and to the temperature employed, ferrous sulphide (FeS), ferric sulphide (Fe_2S_3), ferric disulphide (FeS_2), or magnetic sulphide (Fe_3S_4), or a mixture of these several sulphides, results. The higher the temperature employed and the lower is the degree of sulphurisation of the product; also, since ferrous sulphide (FeS) dissolves both iron and sulphur, if either of these be present in excess, the composition of the resulting sulphides becomes exceedingly variable. Pig-iron heated in a tube filled with the vapour of sulphur absorbs a portion of the sulphur, which it retains even after heating in vacuo during several hours; and hence it is inferred that sulphur may be in this manner imparted to the metal in the blast-furnace, or in other furnaces where sulphurous ores and fuels are employed.

The effect of small quantities of *sulphur in pig-iron* is to make the iron stronger and whiter, and its presence may be thus advantageous in the metal to be used in the foundry for special classes of castings, such as shot, etc.; but the presence of very small quantities of *sulphur in wrought-iron* or *steel* is attended with the worst results, 0·1 per cent. of sulphur sufficing to produce in iron or steel a marked *red-shortness*, or brittleness, at temperatures above redness; although the same metal may possibly be hammered or rolled in the cold state without difficulty. Since iron pyrites is a frequent impurity in the ores and coal used in the production of iron, it becomes necessary, when such ores or fuels have been used, to take special care that only those processes are employed for the conversion of the pig-iron into malleable iron or steel, as will eliminate the sulphur during the process of its conversion, and so prevent the production of red-short malleable iron or steel.

Ferrous disulphide (FeS_2) constitutes the familiar brass-yellow mineral which occurs in radiated fibrous masses, having a strong metallic lustre, and known generally as *yellow iron pyrites, cubic pyrites* or *mundic*; also, in its softer and whiter form, as *marcasite*, or *white iron pyrites*. Heated with access of air, and iron pyrites is decomposed with the evolution of sulphurous anhydride (SO_2). Iron pyrites is commonly employed in this way as the source of sulphur dioxide in the manufacture of sulphuric acid, whilst the residues so obtained, and known as "*Blue Billy*," are used as a fettling for the puddling furnaces in the Cleveland district.

Iron and Phosphorus.—These bodies readily unite under the influence of heat, producing grey readily fusible phosphides. A ferrous phosphide also results when ferrous phosphate is heated to a high temperature along with carbon. Pig-iron also absorbs phosphorus when heated in the vapour of the latter. The presence of very small proportions of phosphorus in any of the commercial forms of iron, whether as pig-iron, malleable iron, or steel, is attended by important and usually most injurious results. Its presence in pig-iron renders the iron more fluid when in the molten state, and thus well adapted for producing light and delicate ornamental castings, but such iron is also very weak, and not adapted to the production of strong heavy castings.

In malleable iron and steel, small proportions of phosphorus suffice to render the metal sensibly harder, without materially affecting its tenacity, but the metal at the same time becomes decidedly *cold-short*. Cold-short metal cracks and breaks, especially at the edges, when worked under the hammer at a temperature below redness, although such material may be readily hammered or rolled when treated at a higher temperature. If in malleable iron or steel the proportion of phosphorus attains to 0·5 per cent. or upwards, then, in addition to being cold-short, the metal also shows a marked falling-off in tensile strength; but the effect of phosphorus is modified by the proportion of other impurities present.

Iron and Silicon.—The union of iron and silicon cannot be effected by the simple heating together of silica and iron, but if carbon be also present, and a sufficiently high temperature be employed, then silicon is reduced from the silica and an alloy of iron with carbon and silicon is obtained. Silicon is thus always present more or less in all varieties of commercial iron, either in combination with the metal, or, as in the case of malleable iron, it may possibly occur only as a constituent of the intermixed cinder always present in such iron. The influence of silicon upon pig-iron, malleable iron and steel will be again referred to.

PROJECTION.—I.

INTRODUCTION.

Practical Plane Geometry treats of figures having two dimensions, length and breadth, and the student must have studied this subject to some extent before beginning the present series of lessons. The student is also supposed to be acquainted with the methods of manipulating the various drawing instruments used by draughtsmen. Some useful hints may be had from a perusal of the lessons on "Drawing for Engineers" (p. 45).

Practical Solid Geometry or *Descriptive Geometry* deals with the representation on the surface of the drawing paper—which has only two dimensions, length and breadth—of points, lines, surfaces, and solids in space of three dimensions.

Projection in Plane Geometry.—In Fig. 1 *a b c d*, etc., is any plane figure; take any point O in the plane and join O to all the points *a*, *b*, *c*, etc., in the given figure. The lines O*a*, O*b*, O*c*, etc., produced if necessary, cut a straight line P Q in the points A, B, C, D, etc. A B C D . . . . is called the projection on the line P Q of the figure *a b c d* . . . . and O is called the pole of projection.

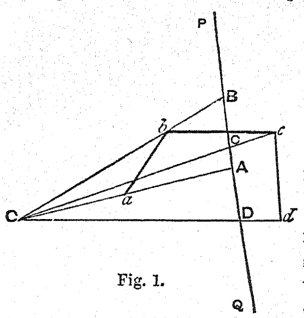


Fig. 1.

Similarly if A B C D . . . . be any figure in space (Fig. 2) and any point O be joined to all the points in the figure, the intersection of the lines O A, O B, ... (produced if necessary) with any plane X is called the projection of the figure on the plane X. If the eye of a spectator be at O, the rays of light from the figure A B C D . . . . in space that reach the eye, are the same as those from the projection *a b c d* . . . . In fact the latter is a picture of the former. O is the pole of projection and the lines through it are called projectors.

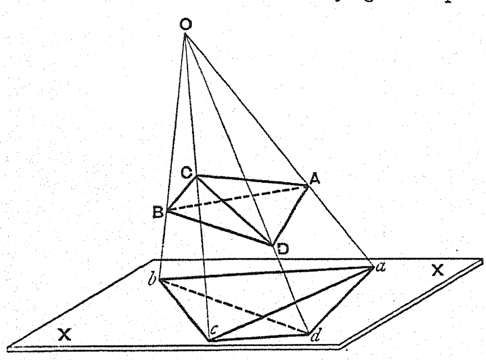


Fig. 2.

Orthographic Projection.—When the projectors are parallel to each other—corresponding to the pole O being infinitely distant—and at right angles to the plane of projection, the projection is called "orthographic."

Inclined Parallel Projection.—Sometimes it is convenient to have the projectors parallel to each other but not at right angles to the plane of projection; we have then an inclined parallel projection (German *Schräge* Parallel-Perspective). This method is specially useful for pictorial representation.

Perspective.—The more general case in which the projectors all pass through a point not infinitely distant is called "perspective."

These lessons will deal chiefly with orthographic projection.

At least two projections are necessary to represent any object. The planes of these two projections are usually at right angles to each other, and are called the horizontal and vertical planes. They are sometimes called the co-ordinate planes. Before proceeding further with these lessons, the student should make for himself a model of the co-ordinate planes and use it in studying the first problems. The model is made as follows: Procure two rectangular pieces of cardboard or thick drawing-paper 9″ × 7″ or larger, and make the slit *a a* (Fig. 3) in the middle of one, and the slits *b b* at the sides of the other. Fold the second piece along the lines *b c*, as shown in the third sketch of Fig. 3, pass the folded part through the slit *a a*, and then flatten out the card. We have now (Fig. 4) a model showing two planes passing through the line X Y, and the planes may be set at right angles to each other or folded together to coincide. V.P. and H.P. will be used as abbreviations for the vertical plane and horizontal plane respectively.

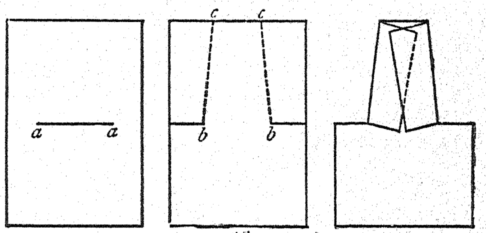


Fig. 3.

PROJECTION OF POINTS.

Plan and Elevation.—In Fig. 4 let the model be held in such a position that the plane A B C D is vertical, and the plane E F G H horizontal. Let P be any point in space; from P drop a perpendicular P p' to the vertical plane, and a perpendicular P p to

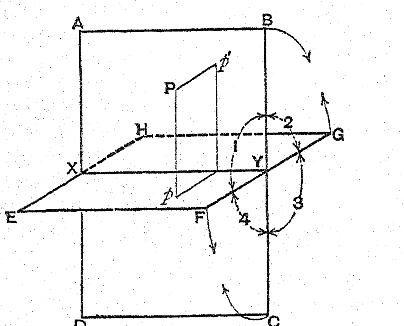


Fig. 4.

the horizontal plane: p is called the "plan" and p' the elevation of the point P. The plan and elevation of a point are sometimes called the "co-ordinates" of the point.

To represent the co-ordinates on the flat sheet of drawing-paper, the co-ordinate planes are folded together as indicated by the arrows in Fig. 4. Any points, lines, or figures on the co-ordinate planes can then be represented on a flat sheet of drawing-paper.

The notation used above in reference to the point P will be used throughout these lessons; that is, a point in space will be denoted by a capital letter, its plan by the corresponding small letter, and the elevation by the same small letter with a dash affixed. We will sometimes find it convenient to refer to a point P in space given by its plan p and elevation p', as the point pp'.

The co-ordinate planes are supposed to extend indefinitely. It will be seen that they divide space into four parts, which are called the first, second, third, and fourth dihedral angles respectively (*see* Fig. 4).

Problem.—Given the distances of a point from the co-ordinate planes, draw its plan and elevation. Let P (Fig. 5) be the given point. The student should take his model of the co-ordinate planes, and, having fixed in his mind the position of P relative to the co-ordinate planes, take his set-square and place it at right angles to the co-ordinate planes and passing through P. Draw C A, C B, the lines of intersection of the set-square with the vertical and horizontal planes respectively. On the set-square draw P p' and P p at right angles to C A and C B respectively. The student should note carefully

(1) p and p' are plan and elevation respectively of the point P.
(2) P p' measures the distance of P from the V.P.
(3) P p ,, ,, ,, ,, ,, H.P.
(4) P p = p' C and P p' = p C.
(5) p C is at right angles to X Y, and
p' C is at right angles to X Y.

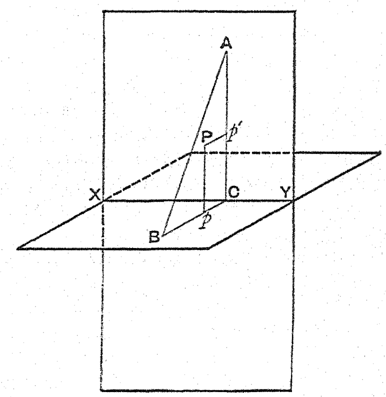


Fig. 5.

From the fifth of these observations we deduce that when the co-ordinate planes are folded together C p' and C p will form one straight line at right angles to X Y (Fig. 6). Hence the following fundamental law in Orthographic Projection :—The plan and elevation of any point are on a straight line at right angles to the ground line X Y. The problem is therefore solved as follows :—Draw any straight line at right angles to X Y (Fig. 6), and set off C p' upwards from X Y equal to the given distance of P above the H.P. Set off C p downwards from X Y equal to the given distance of P in front of the V.P. p and p' are plan and elevation respectively of P.

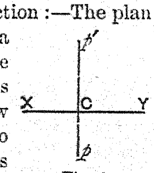


Fig. 6.

If P is below the H.P., C p' will be set off downwards; if P is behind the V.P., C p will be set off upwards.

In Fig. 7, which is drawn to a scale of 3″ to a foot,

the point	A	is	3″ above	the	H.P.	and	1″ behind	the	V.P.
,,	B	,,	2″ below	,,	,,	,,	2″ ,,	,,	,,
,,	C	,,	in	,,	,,	,,	$2\frac{1}{2}$″ before	,,	,,
,,	D	,,	in	,,	,,	,,	in	,,	,,
,,	E	,,	$1\frac{3}{4}$″ below	,,	,,	,,	4″ before	,,	,,
,,	F	,,	2″ above	,,	,,	,,	2″ behind	,,	,,

The student should look at Fig. 7 and write down the positions of the various points with respect to the co-ordinate planes, and compare his results with the distances given above. Also from the distances given above draw the plans and elevations of the points and compare with Fig. 7.

PROJECTION OF LINES.

Let A B be any line in space, and $P_1, P_2, P_3, \ldots$ Fig. 8, any points on it. From $A, B, P_1, P_2 \ldots$ drop perpendiculars to the horizontal plane, and let the feet of these perpendiculars be $a, b, p_1, p_2, \ldots$ These latter points are the plans of $A, B, P_1, P_2, \ldots$ respectively. If the student take his set-square and place it touching the line A B and at right angles to the horizontal plane, a little inspection will convince him that all the projectors, $Aa, Bb, P_1p_1, \ldots$ lie on the surface of the set-square, and therefore the points $a, b, p_1, p_2, \ldots$ lie on the edge of the set-square which touches the H.P. Thus the plans of a series of points lying on a straight line are a series of points lying on a straight line. These remarks evidently apply with equal force to projections on the V.P. We may therefore enunciate the theorem just stated thus :—The projection of a straight line is a straight line.

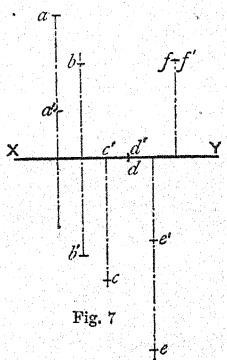


Fig. 7

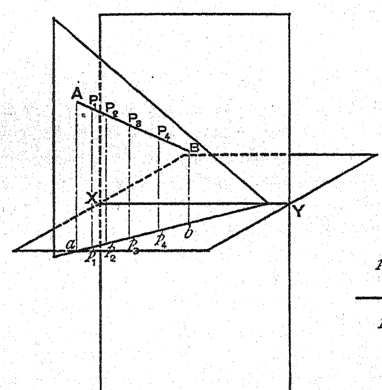


Fig. 8.

If the line A B be parallel to the $\frac{\text{H.P.}}{\text{V.P.}}$ its $\frac{\text{plan}}{\text{elevation}}$ will be equal to the true length of the line. But if the line A B be inclined to the $\frac{\text{H.P.}}{\text{V.P.}}$ its $\frac{\text{plan}}{\text{elevation}}$ will be less than the true length. In orthographic projection under no circumstances can the plan or elevation be longer than the true line in space.

[In the last paragraph in some places two words are placed one a little above and the other a little below the normal line. In reading a sentence the top word or the bottom word must be used throughout. In this way a proposition relative to the H.P., and the corresponding proposition relative to the V.P., can be written in very little space. We will often use this method in the later lessons.]

In Fig. 9*a* the line P Q is parallel to V.P. and inclined to H.P.
,, ,, 9*b* ,, ,, ,, ,, inclined ,, ,, ,, parallel ,, ,,
,, ,, 9*c* ,, ,, ,, ,, parallel ,, ,, ,, parallel ,, ,,
,, ,, 9*d* ,, ,, ,, ,, inclined ,, ,, ,, inclined ,, ,,
,, ,, 9*e* ,, ,, ,, ,, ,, ,, ,, ,, ,, ,, ,,
,, ,, 9*f* ,, ,, ,, ,, at right angles to the V.P.
,, ,, 9*g* ,, ,, ,, ,, ,, ,, ,, ,, H.P.

The student should now solve the following examples. Draw plan and elevation of a line 3″ long

(1) when inclined 30° to the H.P. and parallel to the V.P.
(2) ,, ,, 45°,, ,, V.P. ,, ,, ,, ,, H.P.
(3) ,, parallel to both planes of projection and 2″ above the H.P. and 1″ in front of the V.P.
(4) when at right angles to the H.P. and 1″ in front of the V.P., the lower end of the line being ½″ above the H.P.

The solutions are shown in Fig. 9, *a, b, c,* and *g* respectively.

Fig. 9 is drawn to a scale of 1½″ to a foot.

PROJECTION OF SOLIDS.

The most frequent application of projection is in engineers' and architects' drawings. In this lesson we propose to show how to project some of the simpler geometrical solids ; these being mastered, the student will have no difficulty in projecting any more complicated body.

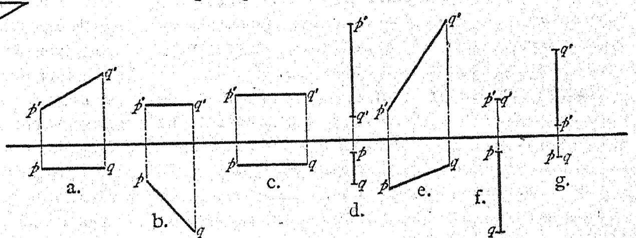


Fig. 9.

Definitions.—The bounding surfaces of a solid may be either plane or curved. A solid whose bounding surfaces are all plane is called a *polyhedron*.

The face of a polyhedron is any one of its plane bounding surfaces.

A *prism* is a solid having two equal opposite and parallel polygonal faces, the other faces are rectangles. There are as many rectangular faces as there are sides in each polygonal face.

The *base* of a prism is one or other of the polygonal faces.

The *axis* of a prism is the straight line joining the centres of the bases.

A *pyramid* has one polygonal face called the base, and all the other faces triangles having a common vertex called the vertex or apex of the pyramid.

The *axis* of a pyramid is the straight line joining the centre of the base to the apex.

A *right prism* or a *right pyramid* has its axis at right angles to the plane of its base.

An *oblique prism* or an *oblique pyramid* has its axis inclined to the plane of its base.

A prism or pyramid is said to be triangular, rectangular, pentagonal, hexagonal, heptagonal or octagonal according as its base has 3, 4, 5, 6, 7, or 8 sides.

A *regular polygon* has all its sides and angles equal. In these lessons when we speak of a polygon a regular polygon is understood, unless the contrary is specified.

A *tetrahedron* is a triangular pyramid, having its base and the three other faces all equilateral triangles.

A *cube* is a square prism having its two bases and the four other faces all equal squares.

An *octahedron* is a solid, having eight equal faces all equilateral triangles. It may be conceived to be formed from two equal square pyramids, whose triangular faces are equilateral, set base to base.

The three solids just mentioned are called regular solids. A regular solid is defined to be one whose faces are all equal regular polygons. There are two other regular solids—the *dodecahedron* with twelve pentagonal faces, and the *icosahedron* with twenty faces, all equilateral triangles.

That there are no other regular solids than the five mentioned above may be demonstrated as follows:—A polygonal face of a solid must have at least three sides. To form a solid angle at least three plane sides are necessary. Also the sum of the plane angles forming a solid angle must be less than 360°. Three, four, or five angles of 60° may, therefore, be brought together to form solid angles, and we get the solid angle of the tetrahedron, octahedron, and icosahedron respectively. If six angles of 60° be brought together, they will all lie in the same plane; the three solids just mentioned are therefore the only regular solids possible with equilateral triangular faces. Consider now a four-sided regular polygon—*i.e.*, a square, the angles of which are 90°. Three such angles may be brought together at a point giving the solid angle of a cube, but four such angles would all lie in one plane. The angle of a five-sided regular polygon is 108°, and three such angles may be brought together at a point giving the solid angle of a dodecahedron. Four such angles would be equal to 432°, which does not fulfil the condition of being less than 360°. Lastly, the angle of a hexagon being 120°, three such angles are equal to 360°, and, therefore, no regular solid can have hexagonal faces. Similarly for polygons of a greater number of sides.

A *cylinder* is a solid, bounded by two equal opposite plane faces—the boundary of each face being a curved line—and the surface formed by straight lines joining corresponding points in the circumference of the two opposite faces.

A *cone* is a solid, bounded by a plane face or base—the boundary of which is a curved line—and the surface formed by straight lines joining points in the circumference of the base to a point called the vertex or apex of the cone.

The $\begin{matrix}\text{cylinder}\\ \text{cone}\end{matrix}$ may be considered the limiting case of a $\begin{matrix}\text{prism}\\ \text{pyramid}\end{matrix}$ when the number of sides in the base is increased indefinitely.

If we speak of a cylinder or cone without further qualification, the base is understood to be a circle.

COTTON SPINNING.—I.

By Henry Riddell, M.E.

THE COTTON PLANT AND FIBRE.

It is intended in the series of lessons now begun to provide a complete treatise on the machinery and methods employed in the cotton spinning trade, and to give such detail as is necessary for the instruction of working students in all the processes employed. It is not intended to supersede the practical work of the mill, but to be an aid and assistant, by means of which the course of observation may be directed, details of machinery explained, and the reasons made clear for the processes adopted. With this view this course of lessons has been designed, and in every page it will be the aim so to develop the subject as to render it most useful to students who wish by conscientious work to make themselves better acquainted with their trade.

It is unnecessary to dilate upon the importance of the cotton trade to England. Whether estimated by the number of hands engaged in it and in its allied and dependent industries, or by the capital employed, or by the figures shown by the record of exports, it stands in the very front of English manufacturing industries. This importance is so well understood, however, by every student that to furnish a number of statistics concerning quantities of cotton imported, and yarn exported, would only occupy space that can ill be spared from the practical teaching intended. It is, however, of great, and indeed of vital import-

ance that the nature of the cotton fibre should be understood, and a knowledge acquired of the important differences presented, in strength, fineness, and other qualities, by the varieties as imported from the countries of their growth. Therefore a considerable space will be employed in considering the plant from which cotton fibre is obtained, its cultivation, and the appearance and qualities of the cottons imported from the chief countries from which the supply is derived.

Cotton is the downy material surrounding and clinging to the seeds of the cotton plant, the *Gossypium*, which is a member of the natural order of the *Malvaceæ*, or mallows.

The plant, in its varieties which yield the fibre of commerce, is confined chiefly to tropical and subtropical countries, and has a range from about the 40th degree north latitude to the 30th southern parallel. An examination of a map of the world will at once show what an immense area is included within these boundaries, and how large the supply could be made if the exigencies of trade required. It will also be noticed what a great proportion of the area is occupied by British possessions. Indeed, a cotton famine, such as that due to the American Civil War thirty years ago, could not now occur to the same extent from the cutting off of any one source of supply.

Included in this cotton zone are the southern shores of Europe, almost the whole of Africa and Australia, a vast portion of Asia, the southern States of North America, and two-thirds of South America; the cotton from each of these sources of supply differing appreciably in appearance and character of fibre, but agreeing in certain respects which are of great value and importance to the spinner.

The *Gossypium* is generally an herbaceous plant varying very much in height, and bearing flowers ranging through different shades of yellow to white. The seeds, which also vary in colour, are contained in five, four, or three valved capsules, which, when ripe, open and expose the fibre. It is at this period that the cotton is collected, as the fibre when immature is comparatively valueless; while if left too long ripe and exposed to the sun, the elastic nature leaves it, and it becomes greatly injured. The bolls or bunches of downy seeds are collected by hand, and spread out to dry; when sufficiently dry the seeds require to be removed by ginning (a process later on to be treated of in detail), and then baled for the market. Under the microscope the fibres of cotton (Fig. 1) are seen as semi-transparent, flattened tubes, with thickened rounded edges and a continuous spiral twist. Their length and general appearance are fairly uniform in a good sample of cotton, but vary within wide limits in cottons imported from different countries. In transverse section (Fig. 2) they are seen to be flattened tubes, the walls almost approaching in one direction; the unripe fibre indeed often appears to be quite destitute of an internal opening (Fig. 3),

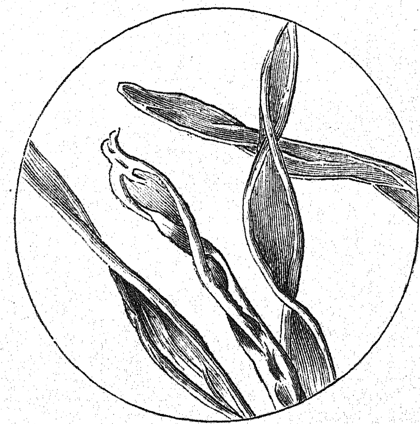


Fig. 1.—Cotton Fibre. (*Magnified about 210 diameters.*)

although when steeped for some time in water these ribbon-like threads swell out and become tubular. It is necessary to guard against unripe cotton in buying, as it does not dye with the ripe fibre, remaining generally white or almost uncoloured by indigo and other dyes. The fibre is really an elongated spindle-shaped cell, clinging to the seed at one end, where the tube remains open,

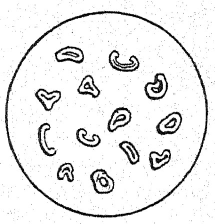


Fig. 2.

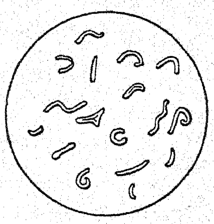


Fig. 3.

(*Magnified about 160 diameters.*)

and tapering at the other to a point. It is to the spiral twist of the fibre that much of its easy spinning power and elasticity is due; although in the very highest class of cotton, the "Sea Islands," with a greatly increased fineness comes sometimes a lessened proportion of twist.

In chemical composition cotton is an exceedingly pure cellulose, having, indeed, only about five per cent. of impurities, consisting chiefly of pectic matters, cotton wax, etc. Cellulose is, in general, present in cell walls, forming the woody part of plants, but usually in a very impure state. It consists of carbon, hydrogen, and oxygen, having

the constituents combined in the proportion of six parts of carbon to five of water. This statement must be understood only as a method of remembering the composition ($C_6H_{10}O_5$) of cellulose, and

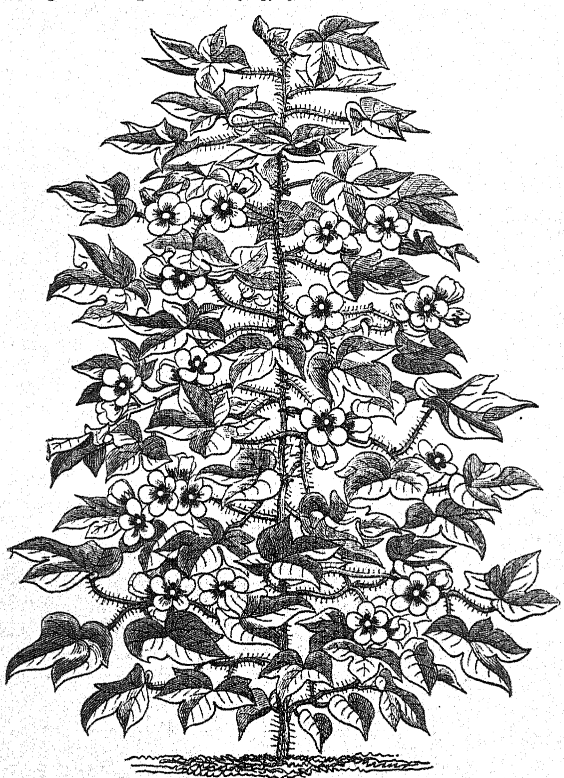


Fig. 4.—Gossypium Barbadense.

not as representing its nature physically. Dilute mineral acids have very slight effect on cellulose, but when allowed to dry on the fibre, become concentrated and rapidly corrode and oxydise it: this effect is very much hastened by heat, and upon it depends the method of "carbonising" or "extracting" cotton from woollen rags as employed in the manufacture of "mungo."

The bleaching process in cotton depends for its success on the removal or decolourisation of the natural impurities before mentioned, which are mostly rendered soluble by alkalies, so that their removal becomes a comparatively easy problem.

Ultimate Structure.—The ultimate structure of the cotton fibre can best be studied by moistening it with Schweitzer's solution, the ammoniacal solution of cupric hydrate, which possesses the property of dissolving cellulose. The cell walls are seen to be composed of bundles of exceedingly fine fibres, encased in, or varnished by, some material which is not cellulose, and not soluble in the fluid. To this varnishing or enclosing material is due the resisting power of unbleached cotton to the absorbing of water. This covering is composed of cotton wax, and forms about two per cent. of the cotton. It is for the purpose of keeping this wax in fit condition that the temperature of cotton mills is required to be kept so high.

Cotton fibre, as has been said, varies very much according to the climate, soil, and cultivation, as well as the variety of the plant; and a knowledge of such differences is essential to the cotton buyer and spinner. Of these four causes, the most efficient is found in the species or variety, and the quality of the seed.

Botanists differ exceedingly in their estimate of the number of species to be found producing the commercial fibre, but the best and most recent authorities agree in limiting the number to about half a dozen well-marked varieties, which will be separately considered.

First then, and as regards fineness and length of fibre, the most important variety is the *Gossypium Barbadense* (Fig. 4), to which belong the different cottons of the "Sea Islands" class.

Second, the *Gossypium Peruvianum*, which may perhaps be considered a sub-variety of the *Barbadense*. This cotton is a long-stapled and fine variety.

Third, the *Gossypium hirsutum*, to which belongs the bulk of the cotton grown in the United States of America.

Fourth, the *Gossypium arboreum*, or tree cotton, which is a native of India, and is remarkable as taking the form of a tree, the other varieties being shrub-like, or as the next or

Fifth variety, the *Gossypium herbaceum*, which is found native in Egypt, Asia Minor, India, and China.

Sixth, the *Gossypium religiosum*. This name is given to two very different varieties by different authorities. By one the name is applied to a sub-species of the *Gossypium arboreum*, while another uses it to represent the shrub-like plants from which is obtained in India and China the tawny cotton fibre known as "Nankin."

As the names employed in the buying and selling of cotton have reference almost solely to the countries of growth, the botanical titles are of little use except as a means of grouping together the produce of different localities; and it is for this

purpose that they will be used in the following pages.

The following table exhibits the chief varieties of commercial fibre with reference to the botanical species from which each is derived, and some particulars as to their nature, uses, etc.

This table is by no means exhaustive, but is fairly representative of the cottons imported into Great Britain.

In reference to the headings of the columns, one or two remarks are required. The varieties themselves as named vary from year to year in quality, so that the information given as to the character of the fibre, its length and diameter, is only an approximate average.

The fineness to which a given fibre can be profitably spun depends so much upon the character of the mill, the class of yarn required, the price of other cottons, etc., that it is a very variable quantity. It will be found, however, that the numbers given in the table are an approximation to actual practice in many mills. The price must also be taken as only a rough average of late markets, and except as showing the *comparative* values, is of little use for reference. In many cases prices quoted are merely nominal when referred to any particular quality, as there are often no cottons of the particular quality in the market. Indeed there are some cottons which are not usually classed as fair, and some which do not always fall so low.

Commercial Title.	Botanic Species.	Description.	Counts spun.	Length of Fibre. Max.	Length of Fibre. Min.	Length of Fibre. Mean.	Mean Diam. of Fibre.	Price for Fair. Per lb. d.
SEA ISLANDS	Barbadense	Very long, silky, and small in diameter of fibre. Clean, but hard to work, owing to frequent presence of unripe or badly developed fibre.	The very finest.	$2''$	$1\frac{5}{8}''$	$1\frac{13}{16}''$	$\frac{1}{1570}''$	13
FLORIDA SEA ISLAND	Do.	Similar to above	150s. to 200s.	$1\frac{13}{16}''$	$1\frac{1}{2}''$	$1\frac{5}{8}''$	$\frac{1}{1570}''$	$10\frac{1}{2}$
FIJI	Do.	Not so strong and very irregular, containing more unripe fibre.	150s. to 200s.	$2\frac{1}{8}''$	$1\frac{5}{8}''$	$1\frac{7}{8}''$	$\frac{1}{1570}''$	$9\frac{1}{2}$
TAHITI ,,	Do.							$7\frac{1}{2}$
PERUVIAN ,,	Do.	Not so clean, nor so long, silky, or fine, as "Sea Islands," golden-tinted.	80s. to 120s.	$1\frac{3}{4}''$	$1\frac{3}{8}''$	$1\frac{9}{16}''$	$\frac{1}{1450}''$	$7\frac{3}{4}$
GALLINI	Do.	A very strong, clean fibre, easy to work, and of a golden tint.	80s. to 150s.	$1\frac{5}{8}''$	$1\frac{3}{8}''$	$1\frac{7}{16}''$	$\frac{1}{1450}''$	$9\frac{1}{2}$
AMERICAN UPLANDS.	Hirsutum	Soft and short, but fairly clean, best suited for wefts.	Up to 40s.	$1\frac{1}{8}''$	$\frac{15}{16}''$	$1''$	$\frac{1}{1260}''$	5
ORLEANS	Do.	The best of the American cottons of this species. Fairly clean and easy to work, and is suited either for twist or weft. Varies slightly in colour.	Up to 50s. or 60s.	$1\frac{1}{4}''$	$\frac{15}{16}''$	$1\frac{1}{16}''$	$\frac{1}{1300}''$	$5\frac{3}{8}$
MOBILE	Do.	Resembles Uplands, but neither so clean nor so strong.	36s. or 40s.	$1\frac{1}{8}''$	$\frac{15}{16}''$	$1''$	$\frac{1}{1260}''$	$4\frac{7}{8}$
TEXAS	Do.	Similar to Orleans, but not so clean, and of a light golden tint.	Up to 50s.	$1\frac{1}{16}''$	$\frac{13}{16}''$	$\frac{15}{16}''$	$\frac{1}{1300}''$	5
SANTOS	Do.	Introduced into Brazil from the United States, is harsher and more wiry, and not so clean.	Up to 42s.	$1\frac{1}{16}''$	$\frac{13}{16}''$	$\frac{15}{16}''$	$\frac{1}{1260}''$	—
WHITE EGYPTIAN	Do.	Is not clean, the ginning being often inferior, the colour is light golden.	Up to 70s.	$1\frac{3}{8}''$	$1\frac{1}{8}''$	$1\frac{1}{4}''$	$\frac{1}{1300}''$	$4\frac{5}{8}$
BROWN ,,	Herbaceum	Soft and silky, strong, clean, and easy to work. The colour is pronounced golden.	Up even to 140s.	$1\frac{1}{2}''$	$1\frac{5}{16}''$	$1\frac{3}{8}''$	$\frac{1}{1400}''$	$4\frac{13}{16}$
HINGUNGHAT	Do.	The best of the Indian fibres, is strong, not very clean, and is of a light golden colour.	Up to 40s. when mxd. with American.	$1\frac{3}{8}''$	$1''$	$1\frac{3}{16}''$	$\frac{1}{1300}''$	$3\frac{9}{16}$
DHOLLERAH	Do.	Very dirty, and not strong. Colour dirty white.	Up to 20s.	$1\frac{1}{8}''$	$\frac{13}{16}''$	$1''$	$\frac{1}{1150}''$	$3\frac{1}{16}$
BROACH	Do.	Fairly clean and moderately strong. Colour strong gold.	To about 28s.	$1''$	$\frac{13}{16}''$	$\frac{9}{10}''$	$\frac{1}{1200}''$	$3\frac{1}{4}$
OOMRAWUTTEE	Do.	Strong creamy fibre, but very dirty as a rule.	Up to 20s.	$1\frac{1}{8}''$	$\frac{13}{16}''$	$\frac{15}{16}''$	$\frac{1}{1150}''$	$3\frac{1}{8}$
DHARWAR	Do.	Fairly clean, but often injured in ginning. Moderate strength and colour golden.	About 24s.	$1\frac{1}{16}''$	$\frac{7}{8}''$	$\frac{15}{16}''$	$\frac{1}{1150}''$	$3\frac{1}{8}$
TINNEVELLY	Do.	Fairly clean, strong, and elastic. Good creamy colour.	24s. to 28s.	$1\frac{1}{16}''$	$\frac{7}{8}''$	$\frac{15}{16}''$	$\frac{1}{1150}''$	$3\frac{3}{16}$
COMPTAH	Do.	Very dirty, of a dusky colour, and weak.	Up to 16s.	$1\frac{1}{16}''$	$\frac{3}{4}''$	$\frac{15}{16}''$	$\frac{1}{1150}''$	$3\frac{1}{16}$
SCINDE	Do.	A very inferior cotton, but clean. Colour dirty white.	12s. or 14s.	$\frac{15}{16}''$	$\frac{1}{2}''$	$\frac{11}{16}''$	$\frac{1}{1150}''$	$2\frac{11}{16}$
BENGAL	Do.	Very dirty and harsh in fibre, fairly strong. Colour golden.	14s. to 16s.	$1''$	$\frac{3}{4}''$	$\frac{7}{8}''$	$\frac{1}{1150}''$	$2\frac{13}{16}$
MADRAS (WEST)	Do.	Fibres fairly strong but very dirty, and owing to dirt, broken fibres, etc., is very difficult to work.	Up to 24s.	$1\frac{1}{16}''$	$\frac{13}{16}''$	$\frac{15}{16}''$	$\frac{1}{1200}''$	3
SMYRNA	Do.	Fairly clean and strong, harsh in fibre, of a dull white colour.	Will spin to about 60s.	$1\frac{1}{4}''$	$1''$	$1\frac{1}{8}''$	$\frac{1}{1500}''$	$3\frac{7}{8}$
PERUVIAN (ROUGH)	Peruvianum	Harsh wiry fibre, fairly strong and very clean. Colour creamy.	Up to 80s.	$1\frac{1}{2}''$	$1\frac{1}{8}''$	$1\frac{5}{16}''$	$\frac{1}{1250}''$	$5\frac{5}{8}$

Commercial Title.	Botanic Species.	Description.	Counts spun.	Length of Fibre. Max.	Length of Fibre. Min.	Length of Fibre. Mean.	Mean Diam. of Fibre.	Price for Fair. Per lb. d.
PERUVIAN (SMOOTH).	Do.	A soft silky variety, very clean, moderately strong. Colour whitish.	Up to 80s.	$1\frac{1}{2}''$	$1\frac{1}{8}''$	$1\frac{5}{16}''$	$\frac{1}{1200}''$	$4\frac{5}{8}$
WEST INDIAN . .	Do.	Rather dirty, rough and harsh, moderately strong.	Up to 50s.	$1\frac{1}{2}''$	$1\frac{1}{8}''$	$1\frac{5}{16}''$	$\frac{1}{1300}''$	$4\frac{3}{8}$
PERNAMBUCO . .	Do.	A fine Brazilian cotton, light golden colour, rather harsh and wiry.	Up to about 60s.	$1\frac{1}{2}''$	$1\frac{1}{4}''$	$1\frac{3}{8}''$	$\frac{1}{1300}''$	$4\frac{1}{2}$
CEARA . . .	Do.	Fairly clean, rather harsh, moderately strong. Colour whitish.	Up to 60s.	$1\frac{1}{4}''$	$\frac{7}{8}''$	$1\frac{1}{16}''$	$\frac{1}{1300}''$	$4\frac{3}{8}$
MARANHAMS . .	Do.	Resembles Ceara in strength and feel, but rather dirty. Colour golden.	Up to about 60s.	$1\frac{1}{4}''$	$\frac{7}{8}''$	$1\frac{1}{16}''$	$\frac{1}{1300}''$	$4\frac{3}{8}$

It will now be necessary to treat in some detail of the nature and cultivation of the cottons included in above table.

The Sea Islands Cotton is generally supposed to be grown from the plant native to Barbadoes, from which the specific name "*Barbadense*" is derived. If this be so, it has varied very much from the

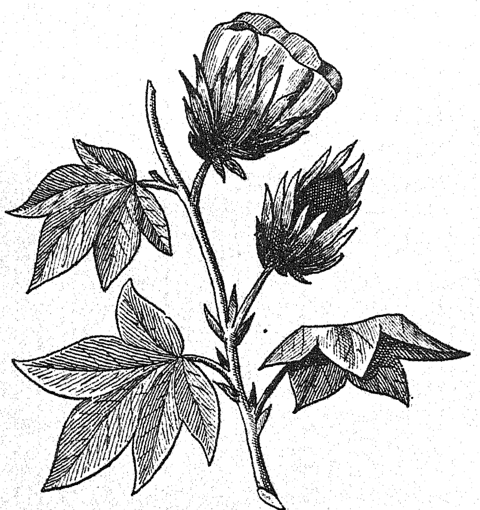


Fig. 5.

original stock, and is now found in its highest class (Fig. 5) on the islands and coasts of Georgia and the Carolinas. It is the most valuable of the commercial fibres, its great value consisting in its fineness, length of staple, equality of twist, and small variation in length of fibre. This cotton is very clean in cultivation, but is unfortunately subject to the frequent presence of undeveloped or unripe fibres, which render it very difficult to work. It is also likely to be injured in ginning, the fibres being broken, making waste in the after-processes. The fibre is strong and elastic, the twists are considerable in number and exceedingly regular, while its colour and appearance are very good. It is light cream-tinted, and beautifully soft and silky. The air and soil of the islands and sea-coasts, and the great care taken in cultivation, have raised this cotton to the very highest class.

Florida Sea Island.—This cotton is of the same nature, grown on the mainland, but scarcely so valuable as the Sea Islands proper. The soil and climate have a great effect on the quality of the fibre; the best classes are grown in the soft, frostless, salt-laden air peculiar to the islands and coasts of Florida, Georgia, and South Carolina, while the same variety rapidly deteriorates when grown inland, and is then known as Florida.

CUTTING TOOLS.—I.

By R. H. SMITH,
Professor of Mechanical Engineering, Mason's College, Birmingham.

TOOL STEEL.

THE good or bad qualities of nearly every kind of tool—its capability of being sharpened to a keen edge, its durability against the bluntening effect of its cutting work—its strength enabling it to exert a large cutting force without breaking—all depend to a very large extent upon the physical quality of the material out of which the tool is made. The material almost invariably used is Steel, and, therefore, at the outset of this subject it will be well to study the qualities and characteristics of Tool Steel.

General Characteristics of Steel.—Steel may be defined as any compound of iron and carbon which can be forged, and which will also harden when plunged hot into water or other cooling liquid. [*See* "STEEL AND IRON."] The tensile strength and the hardness obtained by sudden cooling both increase along with the percentage of carbon. The forging of the material becomes more difficult as the contained carbon increases, and when this reaches 2 per cent. it becomes impossible to forge the steel, because it cracks and crumbles when red-hot under even light blows from the hammer. The tempera-

ture at which different qualities may be successfully forged must thus be less the higher the percentage of carbon; and, as tool steels are all highly carbonised, this rule is of very special importance in the treatment of steel referred to here. It is completely ruined if exposed at the forge to a temperature higher than a certain limit, which varies with the quality, but always lies very much below the welding heat.

Bessemer steel is unfit for tool-making because of certain impurities not eliminated in this process of steel manufacture.

Manufacture of Tool Steel.—The steel suitable for tool-making is prepared from "blister steel," which in its turn is produced from wrought-iron bars by the process called "cementation," this process consisting in the absorption of carbon into the iron bars at a high temperature. The "blister steel" is converted into "shear steel" by faggoting, re-heating, hammering, and rolling. This shear steel is used for some classes of tools, such as pick-axes and spade-edges, that do not require keen edges, and are exposed to violent shocks. But most tools are made from "cast" or "crucible" steel. This is produced by melting fragments of blister steel in crucibles, and casting the molten metal into moulds, so as to form "ingots," which are then hammered, rolled, and forged into the various required forms.

At Crewe tool steel is also made by the Siemens-Martin process.

Combined Carbon.—The melting has the effect of giving much greater uniformity of quality throughout the mass of the product. Without such uniformity the steel is quite unfit for tool-making. Crucible steels containing from $\frac{3}{4}$ to $1\frac{2}{3}$ per cent. of carbon are suitable for different kinds of tools, about 1·1 per cent. being the average for tools for machining, such as turning and planing, and as much as $1\frac{1}{4}$ to $1\frac{1}{2}$ per cent. the average for "edge tools." Before hardening, a part of the carbon exists intimately mixed, but not chemically combined, with the iron; but the larger portion of it is combined as a carbide of iron. The heating effects the combination of the previously uncombined carbon, and the sudden cooling fixes this combination; so that in the hardened steel the whole of the carbon is found to be in the form of carbide. On the other hand, very slow and gradual cooling favours the separation once more of a certain portion, which assumes again the form of uncombined graphite. The resulting product is soft, and the gradual cooling is called "annealing."

Silicon.—The influence of silicon in steel is in the same direction as that of carbon. A smaller proportion of silicon than of carbon makes the metal unforgeable; while to produce the same degree of hardening quality a larger percentage of silicon than of carbon is required. A small quantity of silicon is desirable, as it prevents the formation of "air-holes" in the ingots.

Other Constituents.—Many tool steels contain a certain quantity of manganese, and the presence of this constituent makes forging and welding more easy. It also neutralises to some extent the evil (red-shortness) created by the admixture of sulphur, which it is difficult to get rid of perfectly. Phosphorus is another impurity, which is even more destructive of good quality than is sulphur. Tungsten and titanium are said to have a decided influence in improving the toughness of the steel. Small quantities of copper, silver, and arsenic, are also said to improve its quality. Lastly, nitrogen is an invariable ingredient in steel, and it is now generally admitted that the admixture of *both carbon and nitrogen are necessary* for the production of steel, although the quality is not necessarily high because it contains a relatively large proportion of nitrogen.

Special Brands.—Many special steels have gained a wide reputation for toughness combined with hardness. Among these may be mentioned Mushet's steels, in which titanium, tungsten and wolfram are said to be important constituents. Among long-established English brands of tool steel is Huntsman's, but its good quality appears to be due more to careful mechanical treatment than to special chemical constitution. Edgar Allen & Co., of Sheffield, furnish two extremely fine-grained, hard, and enduring steels, called "adamantine" and "self-hardening." These high-class steels all require to be forged at the very lowest possible heat. Allen's "self-hardening" steel contains ·95 per cent. carbon, ·33 per cent. manganese, and ·21 per cent. silicon. The "Ivanhoe" brand of "self-hardening" steel for milling cutters contains $1\frac{2}{3}$ per cent. carbon, $\frac{1}{4}$ per cent. silicon, $2\frac{1}{2}$ per cent. manganese, and $4\frac{1}{2}$ per cent. tungsten. Both Mushet's "self-hardening" (made by Osborne & Co., of Sheffield) and Allen's "self-hardening" require no water-cooling, but are hardened by being left to cool in the air from a low red heat. Bohler's "Carinthian" steel, made from charcoal-reduced pig, is a very high-class steel of beautifully fine and uniform grain.

Hardening and Tempering.—When a piece of steel has been hardened by heating to a red heat and sudden cooling, it can be partially softened again by reheating to a low temperature and cooling suddenly once more. There is some confusion of practice in naming these two processes. By many the word "tempering" is used to mean the complete double

process of hardening and subsequent partial softening. Others refer to the latter alone—*i.e.*, the partial softening—by the term tempering. It is much to be desired that this latter use of the word should be adhered to, as great inconvenience and frequent misapprehension arise from the use of one term for two distinct and wholly different—in fact, quite opposite—operations.

Colour Scale of Temperatures.—As steel is heated to higher and higher temperatures, its surface, if perfectly clean, assumes successively the following colours:—

Pale straw yellow at about 430° Fahr. This yellow colour gradually deepens in shade until there is reached
Brownish-yellow at about 500° Fahr., which darkens to
Light purple at about 530° Fahr., which gradually deepens and shades into
Dark blue at about 570° Fahr. This blue becomes lighter, and eventually becomes pale blue, tinged with green, at about 630° Fahr.

Urging the temperature still higher, the metal becomes successively—

Black, dark cherry red, glowing red, bright red, orange, bright yellow, white, and scintillating white,

at which last temperature the steel very rapidly burns away in the air, and above which temperature it becomes decidedly pasty as it approaches the melting-point.

Various Effects of Sudden Cooling.—If a piece of unhardened steel be heated through the yellows and blues up to the black temperature, but not so far as to show any red colour, and then be suddenly quenched in some cooling liquid, it will be found to have been hardly altered in texture as exhibited on a fractured surface, or in hardness as tested by the file or the grindstone. If, however, it be heated to the dark cherry red before quenching, it will be found to be both greatly hardened and made finer-grained in texture on the broken section, and also strengthened against a tensive fracturing stress. All these three effects will be increased if the temperature before quenching be raised to glowing red. By quenching at successively higher temperatures than this, the grain is once more made coarser and more open, so that the quenching from a bright red gives much the same fineness of texture as that of the original unhardened bar, while quenching from a white heat leaves it much coarser than this. The strengthening effect also is continuously decreased by quenching from higher temperatures up to bright yellow, and quenching from the white heat produces great brittleness. The hardening effect, on the contrary, is continuously increased by quenching from higher temperatures right up to the dazzling white heat.

The amount of tensile strengthening derived from this hardening process depends greatly upon the cooling liquid, and also upon the percentage of carbon in the steel. Cooling in oil strengthens very much more than cooling in water; and cooling in warm water or salt water, or water with some salt and flour mixed with it, gives greater toughness than plain water-cooling, especially in the case of highly-carburised, that is, tool steels. The strengthening effect, however, is much more strongly marked in mild than in tool steels.

Different Cooling Substances.—The amount of hardening does not only depend upon the temperature from which the cooling takes place—*i.e.*, upon the *range* of cooling—but also very greatly upon the *rapidity* of cooling, the more rapid cooling effecting the greater hardening. Different substances cool more or less quickly, according to their power of conducting heat, and also in proportion to their specific heat. Metals have, therefore, other things being equal, and with the same differences of temperature, much greater cooling power than other substances. Thus a thin piece of steel can be intensely hardened by heating it and laying it between two clean and thick pieces of metal, such as iron or, still better, copper. The difficulty in using solid pieces of metal for the purpose lies in the impossibility of getting them to touch all over the surface of the steel to be cooled. Molten metals, such as tin, lead, and zinc, have been proved experimentally to be efficacious; but the high temperature, especially of the latter, enfeebles their hardening action.

Water-Cooling by Evaporation.—Water is a very bad conductor of heat, and the quenching of steel in water is not effected by the conduction of the heat away into the body of the water. The heat only finds its way into the layer of water immediately in contact with the hot steel, and this layer is immediately evaporated into steam. Provided the steam finds easy escape, fresh layers of water get evaporated rapidly in succession, and since the steam absorbs a great quantity of heat in being generated, the steel becomes very rapidly cooled. It is, however, necessary to allow the steam to escape freely from every part of the surface to be hardened. This is effected by moving the piece through the water and turning it round to and fro. The best possible method of securing a continuous fresh supply of water to the surface is to let a jet in the form of fine spray play upon it. A double or triple jet may be used in order to get different sides acted on equally and simultaneously.

Lead Bath.—A red-hot lead bath is sometimes used for heating, prior to hardening, pieces so large that they are apt to crack in hardening from unequal cooling. It has the disadvantage that the

lead sticks in sharp corners, such as those between the teeth of milling cutters and the grooves of rimers. The lead so sticking interferes with these parts receiving the heat and cooling properly in the subsequent tempering, and therefore such parts are covered with a carbonaceous paste before the piece is plunged in the lead bath, which prevents the adherence of such fragments of lead.

Tempering.—The subsequent tempering consists in removing some of the hardness produced by the quenching, by means of re-heating to a low temperature. The amount of softening is greater the higher the temperature to which the steel is re-heated. Usually the piece is again quenched when the proper low temperature has been reached. The resulting degree of hardness, of course, depends on the quality of the steel, especially upon the carbon percentage, as well as on the tempering heat. The following table of tempering colours is supplied by Jonas and Colver, of Sheffield, for the high-class steel they supply. The different tools are arranged in the list in the order of the successively higher temperatures to which they should be brought for tempering.

Faint straw . . .	Scrapers for brass.
	Steel engraving tools.
	Light turning tools.
	Hammer faces.
	Planing tools for steel.
	Planing tools for iron.
	Paper-cutting knives.
	Wood-engraving tools.
	Flat drills.
	Milling cutters.
	Wire-drawing plates.
	Boring cutters.
Brownish-yellow . .	Screw-cutting dies.
	Leather-cutting dies.
	Taps.
	Chasers.
	Rock Drills.
	Punches and dies.
	Rimers.
	Shear blades for metal.
	Gauges.
	Stone-cutting tools.
	Plane irons.
	Twist drills.
	Wood borers.
Light purple . . .	Cold chisels for steel.
	Axes and adzes.
	Cold chisels for cast-iron.
	Firmer or mortising chisels.
	Cold chisels for wrought-iron.
	Circular saws for metal.
Dark blue . . .	Screwdrivers.
	Springs.

The same firm manufacture steel of different degrees of carburisation, which they number from 1 up to 6. Of these No. 2 is suitable for turning, planing, and drilling tools; Nos. 3 and 4 for rimers, taps, milling cutters, and chisels; and Nos. 5 and 6 for punches, shear blades, screwing dies, and hammers.

Thomas Chatwin, of Birmingham, tempers shear blades and engineers' taps to light straw; gas-fitters' taps and screw-dies to a straw a shade darker, and chasing tools to a dark straw; twist drills and chipping chisels to a bluish-brown, *i.e.*, practically the same as in the above list; the small circular knives of tube-cutters to a purplish-blue; cylindric gauges to a very faint straw, to ensure the best wearing quality.

Cracking and Warping.—In hardening there is much risk of splitting, owing to the cooling and contraction of different parts at different rates, and this also not unfrequently produces distortion. The risks of these mishaps, however, is generally still greater in the tempering, because in the hardening we have at least a uniform temperature throughout the mass to start with, whereas it is very difficult to arrive at an equal temperature throughout in the low heating necessary for tempering. Many different methods are therefore adopted to heat the objects for tempering. Large massive pieces are usually heated over a coke fire in a close oven, and sometimes in a muffle heated either by coal fire or by gas, the most perfect method being that of dipping in a hot bath of oil or molten metal, the particular alloy chosen for the bath being suited to the temperature desired. Small pieces are most frequently heated simply on a hot plate lying over a fire. The focus of the fire being at one end of the plate, a gradually-rising temperature is reached by pushing the objects slowly from one end to the other of the plate. Such a plate, covered with a thick uniform layer of sand, gives greater possibility of obtaining an equal temperature thoughout pieces of unequal thickness, but is somewhat less handy for the workman to deal with if he has to watch many pieces at the same time. A small piece that presents peculiar difficulties in getting the temperature uniform may be heated inside a red-hot iron tube or ferrule. Ordinary workshop tools, such as chipping chisels and turning tools, are usually re-heated by leaving unquenched in the hardening a portion of the bar not desired to be hard, and then allowing the quenched portion to be re-heated by conduction from this part that remains hot. In order to stop the re-heating at the right temperature, the colour is watched, and to make this visible it is necessary to clean the surface perfectly. This can be done by rubbing with a piece of sand or pumice-stone, and where many articles are rapidly passing through the hands of the temperer, a boy is kept to clean up the surfaces by means of a rapidly-rotating buffing-wheel, fed with water and sand or emery-powder.

When the quality of the material dealt with is not very certain and is subject to even slight want of homogeneity, it is well to submit it to thorough annealing by slow cooling before hardening and

tempering, and the desired result will be attained more certainly if the annealing process be repeated more than once. Again, inequality in hardness and texture due to unequal cooling in hardening, may be rectified to a great extent by repeating the tempering process twice, thrice, or even four times. In doing so the re-heating for tempering should be performed as slowly as possible, and oil, or water covered with a layer of oil, should be used as the dipping fluid. The cooling may also be allowed to take place in the air, without the use of any liquid.

The shape of the article to be hardened has, of course, a great deal to do with unequal or equal cooling of its different parts; and this is influenced largely also by certain parts necessarily entering the cooling fluid first, while, on the other hand, the interior parts never come in contact with this fluid. Those parts most freely exposed to the cooling action are most rapidly cooled, while the internal portions cool only gradually, because they do so only by having their heat transferred through the surrounding layers and external surfaces. Pieces which are thin in some parts and thick in others become unequally hardened and are apt to crack and warp. For instance, the hardening of a half-round file so as to keep the face truly flat is one of the most difficult operations in tool-making. Tools with hollow bosses may have the cooling of these central parts accelerated by directing a small jet of water through the hole in the boss. Such bosses, however, are very frequently desired to be softer than the edges. The cooling of the exterior may, on the other hand, be retarded by various devices, such as clamping upon them pieces of iron shaped to fit closely, or smearing them over with a coating of loam bound on with wire. A coating of prussiate of potash similarly bound on is also recommended, the prussiate of potash having an extra hardening effect by further carbonising the surface layer. This latter process appears to be of particular value in preventing cracks at sharp re-entrant corner angles. A stout wire is wrapped into the corner, and the prussiate is plastered over it. A coating of prussiate of potash is also sometimes used to protect the surface from oxidation in heating for hardening over an open fire. Such oxidation is, of course, to be specially guarded against when the piece to be operated on has been tooled over and nicely finished. Here the exclusion of air from contact with the steel surface is the object to be aimed at.

Pieces that are found to cool or heat unequally, and, therefore, crack in spite of any of the above precautions, can frequently be dealt with successfully by somewhat modifying the shape in such a way as not to interfere with the necessary strength, and yet to reduce the mass of metal at those parts which cool less rapidly than the others.

It is evident that uniform heating is as important in order to avoid cracking as is uniform cooling, and the same causes as regards shape, etc., make it difficult to attain uniformity in the heating process. The difficulty in heating, however, can be to a great extent overcome by *slow-heating*. If the *rate* of heating were indefinitely small, every part of the metal would certainly come to almost exactly the same temperature. Hence arises the value of the process termed "soaking," which simply refers to the finishing of the heating process very slowly. The use of gas stoves in this trade has not yet, in the opinion of the author, been sufficiently developed. By them a closed chamber can be obtained with very uniform temperature at every point of each level surface, a graduation of heat being obtained from top to bottom of the stove, and furthermore the flame can be made wholly non-oxidising (or even carburising if desired) by suitable regulation of the relative supplies of gas and air.

In forging before hardening, the hammering on the anvil should be continued until the metal is quite cool, and a ragged edge at the point of the tool should be carefully avoided. If the tool has to be subsequently re-hardened, it should be first heated to a low red heat, hammered until cool, and then again heated for hardening. The hammering gives fineness of texture and toughness.

In heating for tempering in oil, or with the article smeared over with oil or tallow, George Ede says that the first appearance of smoke rising from the oil indicates the attainment of the temperature of 450° Fahr. When the smoke rises copiously, the temperature of 500° Fahr. has been reached, corresponding to the "brown" colour; still more abundant black smoke indicates 530° Fahr., or the "purple" temper; and 580° Fahr., or "blue" temper, is reached when the oil takes fire when a lighted match is brought in contact with it.

Tool steel is much more expensive than any kind of cast or wrought iron, or mild steel. It is of importance, therefore, that scraps of tool steel should not be thrown aside as waste, but should be collected for remelting in the crucible, especially as such remelted scrap makes the best quality of steel. Steel-makers buy such scrap from engineering workshops. The bulk of it consists of stumps of turning and planing tools and of chipping chisels worn and ground too short for further use, and of broken files. Files that are not broken, but merely bluntened, are not remelted, but merely softened, recut, and rehardened. Milling cutters with broken teeth are softened, re-turned, and recut.

PLUMBING.—I.

By a Practical Plumber.

INTRODUCTION.

There is probably no trade or craft that is of greater antiquity than that of the plumber. Of the discovery of lead we know nothing, and we can only conjecture that it was in all probability found by accident, like glass and many other important materials. Lead is plentiful in many parts of the world, and this fact, together with that of its being easily reduced from its ores, and the facility with which it can be manipulated as compared with iron or copper, will easily account for its being highly valued by primitive races. It would be very interesting to trace the gradual progress of the art of lead-working from the earliest ages to the present day; but this would be foreign to the purpose of these lessons.

There is, it need hardly be said, a great difference between the plumber of the present day and the plumber of, say, a hundred years ago: at that period little or nothing was known or written about sanitary science, as we understand the term, with reference to plumbing. The drainage of cities and towns was in a very unsatisfactory and unsanitary condition as regards the main drainage; and the sanitary arrangements (if such they could be called) of dwellings were faulty to a degree. No principles were laid down by responsible authorities for carrying out the drainage and plumbing work in a proper manner. Architects and surveyors had very little knowledge of these important subjects, and consequently many blunders were perpetrated.

But by degrees light broke on the subject; one by one new inventions were brought out. Sanitary science, sanitary plumbing, and sanitation became household words, and plumbing found itself elevated from a trade to a science. Old things began to pass away and new things to take their place. All that was new, however, was not good; many ideas and schemes were brought out by would-be sanitary reformers, and conclusively proved (by them) to be the very best of all possible schemes. But time proved most of them to be unworthy. Yet even faults and failures had their uses: people began to take some interest in the sanitary fittings of their houses, and to realise that it was better after all to pay somewhat more to the plumber and have a good job made of the work than to exercise a false economy. First of all there is a tendency to under-estimate the value of good plumbing work, and to pare down prices to the lowest level. For example, two plumbers are asked to give a price for the work of a house; one, by specifying cheaper material and fittings, and leaving out various trifling details, gets his estimate perhaps £5 cheaper than the conscientious man who has endeavoured to plan out a good and workmanlike job, and in nine cases out of ten the cheap man will get the work. This is bad in several ways: the cheap man is confirmed by his success in his policy of cheap and nasty; the other man, finding his honesty of dealing unappreciated, is tempted to lower his standard of work, and the general public are the sufferers.

Next, there are a great many persons who profess to do plumbing and sanitary work who have very little qualification for it beyond a signboard over their shops with the words "plumber and sanitary engineer" thereon, and a few traps, closet-pans, and plumbers' fittings in their windows. The general public having no occult powers of distinguishing the skilful workman from the duffer are just as likely to employ the duffer as they are the skilled man. Lastly, we have to take into consideration the conservatism of workmen. Workshop methods and maxims that have been handed down without questioning from generation to generation are not easily displaced, especially as we know that the British workman frequently is very much prejudiced against book-learning, and if he has managed to get through his apprenticeship and obtained a job as a full-fledged journeyman, thinks that no one can teach him anything more, and that what he does not know is scarcely worth learning. Something, however, has been done to remedy this state of affairs.

The Plumbers' Company formulated some years ago a system of registration, by means of which any plumber possessing the requisite knowledge could pass an examination and take a certificate of registration, and be entitled to term himself a registered plumber; and though it by no means follows that a registered plumber is always a better workman than his unregistered brother (for there are many good workmen who have never taken the trouble to become registered), yet the registration certificate shows that a knowledge of the subject is possessed by the holder, and that he understands the practical portion of his work as well as having some knowledge of the scientific principles underlying his trade. Thus the public have this much protection afforded them, that they can, if they will, employ men who can give some proof that they understand their business.

All young men engaged in plumbing work should endeavour to perfect themselves in the scientific branches of their work as well as in the practical. It should be the aim of every plumber to know not only the way to do a thing, but why it should be done that way; to be able to explain the differ-

ence between a good job and a bad one, and to be able to carry out a piece of work so that he need not care who might examine or criticise it when finished.

WORK OF THE PLUMBER, THE WORKSHOP, SOME TOOLS AND APPLIANCES AND THEIR USES.

The word "plumber," from the Latin *plumbum*, lead, signifies of course a lead worker or manipulator, and such is one of the branches of trade of the modern plumber; but the word has now a much wider application.

The plumber of to-day not only makes soil-pipes, traps, bends, cisterns, etc., and fixes closets, sinks, lavatories, and other sanitary appliances, but he must also be acquainted with hot-water work, including the fitting up and repairing of kitchen-boilers, and the necessary pipes for the hot-water supply to baths, sinks, etc. In many country shops we find the plumber doing gas and cold-water fitting, and very often he combines with these some knowledge of electric and other bells, not to mention a little smithing and lock-work thrown in occasionally.

In these lessons I will deal with the principal work of the modern plumber.

Plumber's Workshop.—The workshop should be large, well lighted, and well ventilated to take off the fumes and noxious smells that are sometimes unavoidable, such as when cleaning closets, burning off the iron work, etc., as well as the fumes from metal-pots, and so forth. A forge is very useful, and at any rate there must be a fire-place with a strong iron bar built in across it to suspend pots of metal over the fire, which should not be built too high up. A portable fire or "devil,"

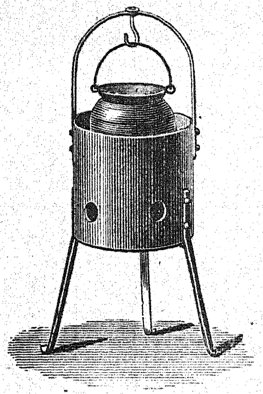


Fig. 1.

as it is called (Fig. 1), is also a necessity to take out on jobs. In lieu of, and sometimes as an accessory to, the open fire-place before mentioned, a plumber's stove (Fig. 2) is used; these are made of cast iron, and are strong useful articles. Figs. 3 and 4 show two metal or solder-pots of different shapes: Fig. 4 is often preferred to Fig. 3, for the reason that the metal, when cold, will turn out should it be required. I have also usually found them thicker, which is an advantage, as the metal is not so likely to burn as in a thin pot, and the heat is retained longer when off the fire, which is a consideration when at work in the open air.

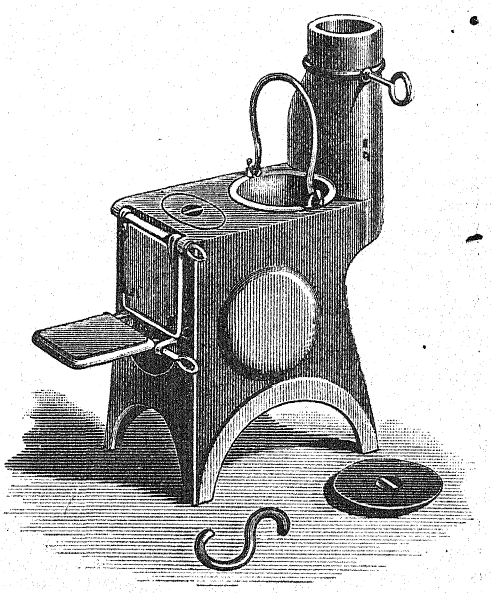


Fig. 2.

Fig. 5 shows the plumber's soldering iron proper as distinguished from the copper-bit. Various sizes of these are required for different work, those

Fig. 3.

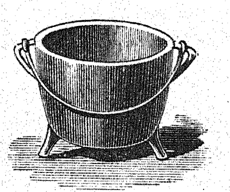


Fig. 4.

used for joint-making being smaller than for roof-work and cistern-lining.

It will be seen that these irons are hooked at the part held in the hand; this is for convenience in pulling up to roofs from the ground,

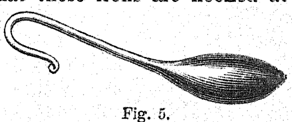


Fig. 5.

to save the plumber's mate from trotting up and down a long ladder or stairs; also for convenience in handling; and lastly, because wooden handles are not suitable for these irons even if a straight form were desirable.

Ladles (Fig. 6) are required of various sizes, from a small one holding about $1\frac{1}{2}$ pound of metal to

those of 6 or 7-inch diameter. In choosing ladles select wide-handled ones, as they afford a firmer hold; some plumbers double the handle back bow-shaped; it is a good plan if the handles are long enough to allow it.

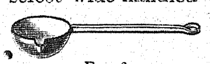


Fig. 6.

Caution.—When picking up a ladle to skim or put into a pot of metal, always make sure that it is not damp. Many accidents have happened through carelessness in this: the steam generated under the surface of the metal by the wet on the ladle forces up the lead in a shower, often into the face of the user; it is a good plan to put the ladle on the fire for a minute or two.

Fig. 7.

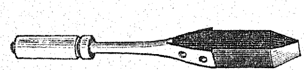


Fig. 8.

Figs. 7, 8, 9 show the shape, etc., of various copper bits used for joint-making, pipe-soldering, etc.; these irons can be purchased at the tool-merchant's, but to my mind they are not correctly made, the shanks are usually too long and the handles badly fixed; a lot of copper also is wasted by being riveted between the two wings of the shank. An iron made like Fig. 10 can be used up to the last piece; the shanks of soldering irons should be drawn out tapering and pass right through the wooden handles and clenched or riveted over at the end (*see* dotted lines, Fig. 9), and a groove should run round the handle at the top, and copper wire bound round to prevent the handle splitting; this is better than a ferrule, which is constantly slipping down the shank. The shavehooks (Figs. 11, 12, and 12 A) are used for shaving the edges of soil-pipes, ends of joints, etc., previous to soldering. The bent one is for use where the straight one would be awkward to use. Some little practice is required even to "shave" correctly; if not held at the correct angle, instead of the lead shaved having a smooth, bright appearance as if planed, it will be rough and ribby. Figs. 13, 14 show the "turnpin"; this is called all sorts of names. I have heard men say: turnpin, tanpin, tampion, taftpin, and pipe-opener. A pipe-opener it undoubtedly is; but we will through these lessons call it by the (I think) most generally known term of "turnpin." Its use is to open the end of one piece of pipe to receive the other, in order to make a joint or connection between them. It is used by grasping the pipe to be opened in the palm of the left hand, and holding the turnpin lightly by thumb and finger and smartly tapping it with a hammer; it is preferable to use a light hammer with smart blows than a heavy hammer, even for largish pipes. Plumbers doing much pipe work require several of these, varying in size for different work from $1\frac{1}{4}$ inch across the top, $\frac{1}{4}$ inch at bottom, and 2 inches long, up to 7 inches across, $2\frac{1}{2}$ inches at bottom, and 10 inches long—this latter is for soil-pipe. The turnpins usually sold are made like Fig. 13; but Fig. 14 is the best shape for the two smallest sizes: they should be made of best box, or, better still, lignum vitæ.

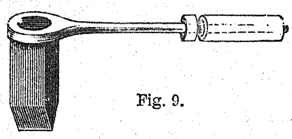


Fig. 9.

Fig. 10.

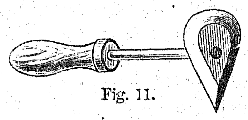


Fig. 11.

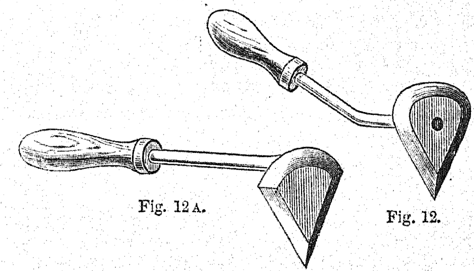


Fig. 12 A. Fig. 12.

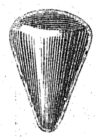


Fig. 13.

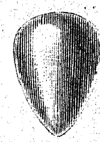


Fig. 14.

SOLDER-MAKING.

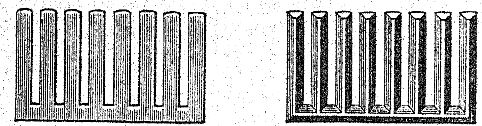
Previous to describing the making of solder, let us see what it is composed of. Briefly speaking, solder is an alloy of metals used for the purpose of joining metals together. The metals of which solder is composed are mainly lead and tin; bismuth is added in some cases to make a very easily fusible solder for special purposes, and, in some cases, mercury is added for the same purpose. The writer, however, in the course of twenty-five years' working experience, has found simple alloys of tin and lead serve his purpose for anything he has required.

Description of Various Solders.—The following list is a reliable one for practical purposes:—Plumber's solder for wiped joints, 2 parts lead, 1 part tin (modified slightly according to circumstances). Coarse solder for copper-bit work, equal parts of lead and tin. Fine solder for copper-bit work, 4 parts tin, 3 parts lead. Blowpipe solder, 5 parts tin, 3 parts lead. Very fusible solder,

suitable for finest pipe-work, such as pneumatic bell tube, etc., 2 parts tin, 2 parts lead, 1 part bismuth. Scores of other slightly varying formulæ could be given, but to no useful purpose, as the above will serve for all classes of work.

Preparation of the Solder.—Use, for making plumber's solder for wiping, pure pig lead where possible; if this is not available, use clean cuttings of sheet lead or pieces of lead pipe. Do not use any pieces of metal that have been run down before, as you know not what may have been mixed with them, and nothing will tell the tale quicker of there being anything wrong in its composition than plumber's solder. Zinc, above all things, must be kept out of, and as far as possible from, it. Melt the lead first in the metal pot over the forge, stove, or "devil," skim off the dross and impurities with a ladle, then add the tin, stir well together with a piece of stick, throw in a little resin to clear it; again skim off the dross, and pour out into moulds of any convenient size and shape. Commercial solder, by which I mean that sold by the dealers and lead merchants, is made in what are called "casts" of about 56 lb., run in a mould of damp sand. Fig. 15 shows a "cast" of solder.

Copper-bit Solder.—Melt as previously described for plumber's solder the proper proportionate parts



A Fig. 15. B

of lead and tin, and run into sticks about 16 or 18 inches long. Cast-iron solder moulds can be purchased or V-shaped moulds can be made in sheet-iron; for convenience in handling, "stick solder," as this is termed, should not weigh more than 1 lb. or thereabouts to the stick. It frequently is the case that fine solder has to be made from what we may term odds and ends, say some old pewter pots, pieces of tin pipe, plumber's joints (known as "hards") cut out of lead pipe, and so on; in this case it is advisable to melt these all down first—the coarser metals first, adding the pewter last: now we have a mixture, but we do not know whether it is too fine or too coarse. To find out, run out a stick and allow it to get quite cool; then take it in both hands and bend it, holding it close to the ear. Should a pronounced crackling be heard, it clearly indicates that it contains too much tin; should the crackling be very faintly discernible, it may be concluded that the solder is very good and fit for use, and if not wanted extra good, about 5 per cent. more lead may be added. Should it bend softly without a sign of the crackling, it requires more tin, which should be added tentatively, testing after each addition of (say, you are making $\frac{1}{2}$ cwt.) about 2 lb. at a time. Solder can also be estimated by the look of it. Run out a piece about the size of a five-shilling piece on the anvil, or an iron plate, and watch it; should it set quickly a dull bluish-grey, it shows too much lead; should its colour be white and little pits all about it, it shows too much tin; should it keep its silvery appearance for several seconds and gradually set all over with a uniformly bright and smooth surface, it may be considered to be satisfactory.

Blow-pipe Solder.—This not being required to be made in large quantities, is best melted in a good-sized ladle, and the method of running it out is as follows:—Drill a hole $\frac{1}{8}$ inch in diameter in a small ladle, about $\frac{1}{4}$ inch down from the edge, have an iron plate perfectly level, and dip out a ladleful of solder; cant the ladle, so that the solder flows above the small hole, at the same time drawing the ladle back about 18 inches: the metal flows in a small stream through the hole and sets rapidly on the cold iron plate in strips of a suitable size for the blow-pipe. This solder, to keep it clean and bright, should be kept in a canister.

DRAWING FOR CARPENTERS AND JOINERS.—I.

THE object of the present series of lessons is a thoroughly practical one—namely, to teach the drawing required by Carpenters and Joiners, whose work enters so largely into all building operations. It is hardly necessary to say this drawing is something more than mere copying. Drawing is said to be the language of the workshop, and certainly a drawing conveys information to workmen that mere verbal explanation could not possibly do. Although the first lessons in this series consist of making scale drawings from dimensioned sketches, by the time the student has gone through the series, he should be able to represent on paper his ideas with respect to any particular piece of building construction. Such is the chief aim of mechanical drawing in all its branches.

Drawing Instruments.—The instruments used are the same as those used for engineering drawings; the student, therefore, before beginning an exercise should refer to the lessons on "Drawing for Engineers," and study carefully what is there said about drawing instruments and their use.

Pencil Drawings.—The technicalities of preparing a carpenter's drawing are pretty much the

same as for an engineer's drawing. Here again the student is referred to "Drawing for Engineers," and is recommended to read the paragraphs on

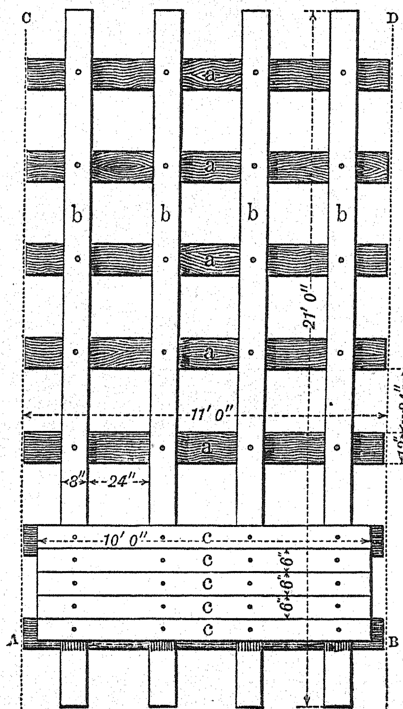


Fig. 1.

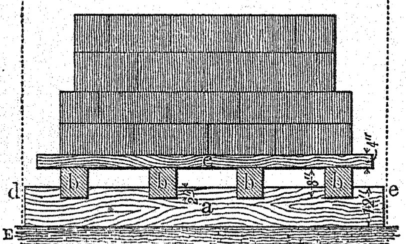


Fig. 2.

"pencil drawing." He may also work out the first few examples there given, which are intended to give facility in the use of the T-square, set square, drawing-scale, and pencil. Presuming that he can do these examples with some degree of neatness and accuracy, the following examples may be attempted.

Example 1.—Timber platform on which a foundation is to be erected. Fig. 1 is the plan showing the transverse sleepers *a a a* which rest direct on the soil, the longitudinal sleepers *b b* which rest on the top of the transverse sleepers, and part of the planking *c c*. Fig. 2 is a section taken midway between two transverse sleepers, and shows the longitudinal sleepers in section, the transverse sleepers and planking in elevation. Draw to a scale of half an inch to a foot. We will go into the details of this drawing rather carefully, in order that it may serve as an example for the student of the method of attacking more complex drawings.

(1) With the T-square draw the line A B (Fig. 1) faint.

The longitudinal sleepers *b b* are marked 8″ square in section and 24″ apart; so

(2) Set the edge of the drawing-scale along A B and mark off 8″, 24″, 8″, 24″, 8″, 24″, 8″ in succession. Note, these dimensions must be set off direct from the edge of the scale, a pencil mark being made on the paper exactly at the proper mark on the scale. Dividers or compasses must not be used for this purpose.

The transverse sleepers are marked 11 feet long, and by a little addition and subtraction it is seen that their ends project 14″ beyond the longitudinals. These distances may be marked along A B in the same manner.

(3) Through the pencil marks on A B draw with the set square the lines indicating the longitudinal sleepers and the ends of the transverse sleepers A C and B D, faint.

(4) Set the edge of the drawing-scale along B D, and mark off the seven transverse sleepers 12″ wide and 24″ apart.

The longitudinals are marked 21 feet long, and therefore project 1 foot beyond the transverse sleepers; mark off these distances along B D.

(5) Draw the ends of the longitudinals firm, and draw the transversals, as shown in Fig. 1, firm. The latter lie below the longitudinals, and therefore the lines indicating them stop at the longitudinals, or they may be drawn dotted if desired. In the figure five transversals are shown, the planking of the platform being shown on the remainder of the plan. The lines just drawn are perfectly determined in position by faint lines already on the drawing, hence we have asked the student to draw them at once firm.

(6) Rub out the parts of the faint lines A C and B D that are not required, and also the faint lines projecting beyond the ends of the longitudinals, and firm in the remaining faint lines.

(7) The planking *c c c* is 6″ × 4″ × 10′ 0″ long, and may be drawn in the same way as described above.

The section (Fig. 2) must be properly projected

from Fig. 1. It will be noticed that transverse dimensions in Fig. 2 are the same as in Fig. 1. The vertical dimensions in Fig. 2 must be marked

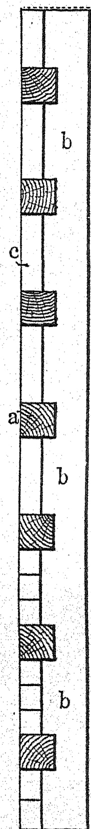


Fig. 5.

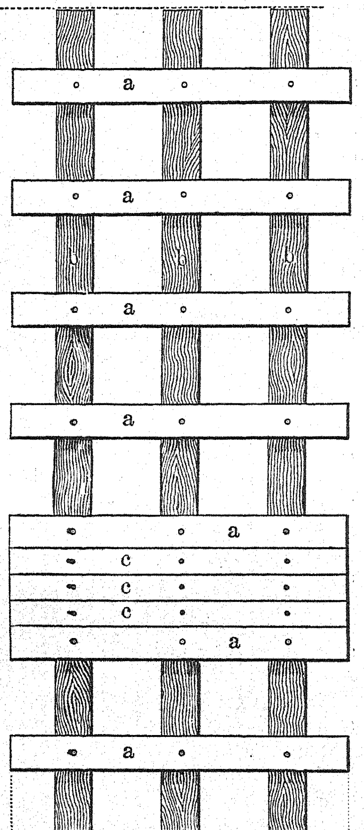


Fig. 3.

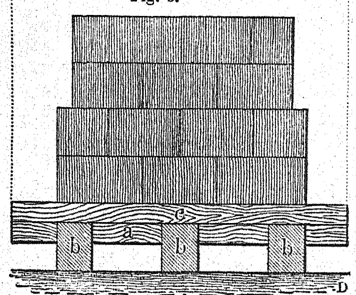


Fig. 4.

off direct from the edge of the scale. Notice that there are notches 2″ deep in the transverse sleepers to receive the longitudinals.

The spaces between the sleepers are well rammed up to the top of the sleepers, the planks may then be said to rest on a solid base. The planks should be spiked to the sleepers with wooden pins.

Example 2.—Figs. 3, 4, and 5 are plan, end elevation, and longitudinal elevation respectively of a platform on which the longitudinal sleepers *b b* rest directly on the ground, and are kept in place by the cross-sleepers *a a* which rest upon

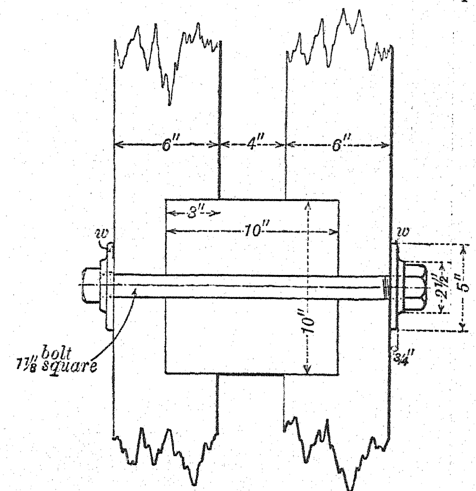
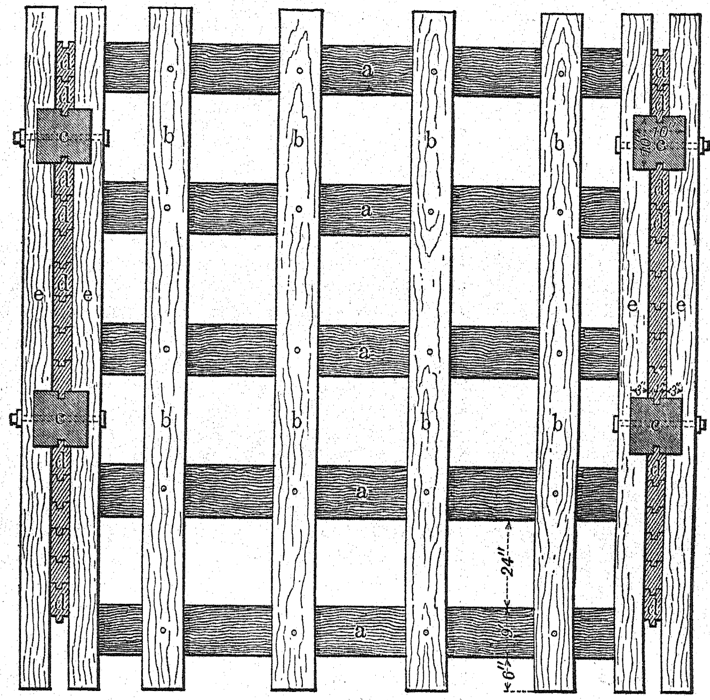


Fig. 13.

them. There are notches cut in the longitudinals, so that only half the thickness of the cross-sleepers stands above the longitudinals, as is clearly shown in Fig. 5. The dimensions of the sleepers are the same as in Example 1.

It should be mentioned here that the figures relating to Examples 1 and 2 must be regarded as mere sketches: they are not drawn to scale, and therefore the student must not merely "copy" them. The figured dimensions must be carefully attended to.

Example 3.—Fig. 6 is the plan and Fig. 7 the section of a network platform for a foundation where the soil is of a soft character, and liable to be pressed outward by the weight resting upon it, but still not sufficiently so to render sheet piling absolutely necessary. Strong piles *c c c*, 10″ square in section, are driven down into the soil; these are connected by horizontal planks *e e*, 6″ × 8″ in section, placed on each side, and bolted through the piles. In the space left between these planks a wall is formed of timbers *d d d d*, 4″ × 8″ in section, which are driven down into the soil, but not so far as the piles *c c*. Figs. 8 to 12 show different forms of joints for the planking *d d*; Fig 8, rebated; Fig. 9, splayed at one edge, and recessed at the other; Fig. 10, ploughed and tongued. In Fig. 10 the tongue is shown in two forms, square and tapered, and in Fig. 11 it is worked into the



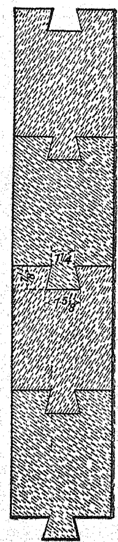


Fig. 6.

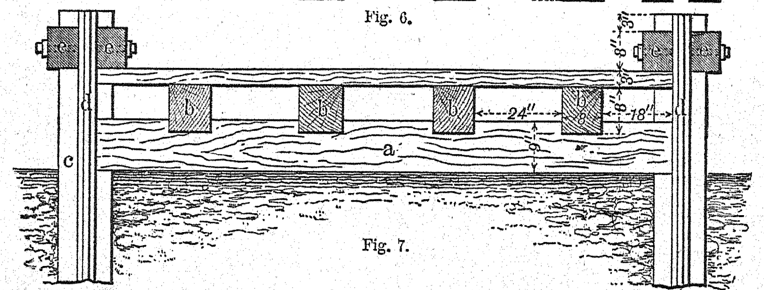


Fig. 7.

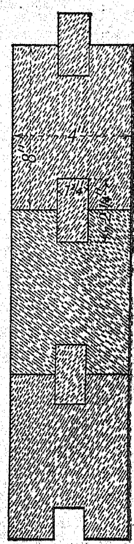


Fig. 12.

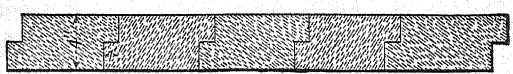


Fig. 8.

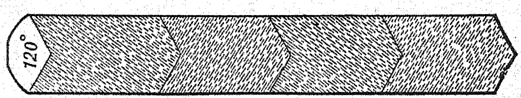


Fig. 9.

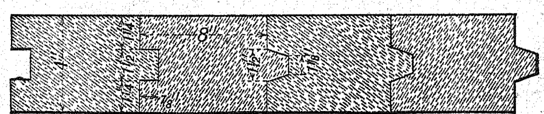


Fig. 10.

dovetail form. Fig. 12 shows the planks joined by a loose tongue.

Fig. 13 shows the bolt and nut for bolting the horizontal planks *e* on each side of the piles *c c c*. In order that the wood fibres may not be damaged by screwing up the bolt and nut, the cast-iron washers *w w* are introduced between the nut and the plank, and also between the bolt-head and the plank. The pull of the bolt is in this way distributed at once over a large surface of the plank.

The ends of the piles *c c c* are pointed and shod with a cast-iron shoe, and an iron ring is placed round their upper ends to prevent the piles splitting by the violence of the blows necessary to force

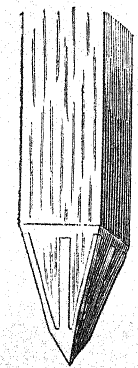


Fig. 14.

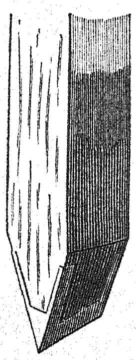


Fig. 15.

them down. Fig. 14 shows the pointed end with the cast-iron shoe. In sheet piling the ends of the piles are formed as in Fig. 15.

Draw Figs. 5 and 7 to a scale of half an inch to a foot. Figs. 8 to 12 may be drawn separately to a larger scale, say 3 inches to a foot, before showing the joints of the plank, in Figs. 6 and 7. Fig. 13 should be drawn full size. In "Drawing for Engineers" the method of drawing bolts and nuts is explained at some length, and the student should adhere closely to the instructions there given. The student will find it advantageous to draw some of the earlier examples a second time, taking care, of course, to avoid any errors or inaccuracies made in the first drawing. The second drawing will not, as a rule, require nearly so much time as the first one, since the student knows better the construction of the object represented, and also should know the exact meaning of every line of the drawing.

In the earlier drawings there should be no attempt made to represent the grain of the wood as shown in Figs. 1—7, but the drawings should be left in outline in pencil as in Fig. 13. All the student's attention must be devoted to the production of these pencil drawings in firm, uniformly thick lines.

ELECTRICAL ENGINEERING.—I.

By Edward A. O'Keeffe, B.E.,

Senior Demonstrator in Electrical Engineering, City and Guilds of London Technical College, Finsbury.

INTRODUCTION.

The science of Electrical Engineering is one which has attained its present prominent position in what may be called a phenomenally short space of time. Its growth within the Victorian era has no parallel among the kindred sciences. It would seem as if men during that time were endeavouring to make amends for the lethargy into which their forefathers had apparently fallen for something like two thousand years; for it is fully two thousand years since the two primary discoveries were made in electricity and magnetism. The first was, that if a piece of amber was rubbed it acquired the property of attracting light bodies; the second was, that certain black stones, found at that time in Magnesia, in Asia Minor, possessed the property of attracting iron. These stones were called magnets, from the district in which they were first found. Here were two facts thoroughly recognised some five hundred years B.C., and yet it was not till some fifteen hundred years later that the discovery was made that if the magnet was suspended by a thread it took up a position pointing north and south; and that it took up this position at no matter what part of the earth the experiment was made. From this peculiarity it received the name of the *loadstone*. The importance of this discovery on navigation need scarcely be pointed out.

The next great discoveries were those made by Dr. Gilbert, in England, published at the end of the sixteenth century. He showed that the property which was supposed to be peculiar to amber, when rubbed, was common to a large number of other bodies, notably to glass, most of the precious gems, sulphur, resin, etc.; in fact, to those bodies which are now known as non-conductors. But though the effects obtained from these bodies were perfectly distinct, still they were necessarily extremely feeble. It now became important to exaggerate these effects, and this object was successfully accomplished by Otto Guericke, who mounted a large sulphur ball on a spindle, which was turned by one person while another held his hands on the revolving sulphur ball. The necessary energy in the form of friction was thus supplied for the production of electricity, and when the machine was worked in a dark room a series of sparks was given off from it. This *frictional* machine was subsequently modified and considerably improved; but the most that could be got out of it was a series of sparks more or less bright,

which could be made to pass between two points or knobs, one of which was attached to the rubbing, and the other to the rubbed, surface.

All that these machines were capable of doing could, however, be done very much better by the class which succeeded them, namely, *influence* machines. The action of this machine depended on a principle entirely distinct from that of the frictional machine; and in respect of the brightness and length of the sparks which could be obtained, the influence was in every way superior to the frictional machine.

These machines undoubtedly showed an advance in the science of electricity, and it might even be said that the spark obtained from them was the original form of the electric light; but when looked at from a commercial standpoint, it must be confessed that the electrical machine, as it then existed, was nothing better than an interesting scientific plaything, highly dangerous to ordinary mortals, and not quite safe in the hands of those who understood it best. It supplied intermittent electric currents forming sparks, but the supplying of a continuous current, no matter how weak, was a task utterly outside its scope; and it was the solution of this problem—how to supply a continuous current—that has made the names of Galvani and Volta so familiar to everyone who takes any interest in electricity.

While experimenting with recently-skinned frogs' legs, about the year 1785, Galvani discovered that if an iron wire which is touching the crural (leg) muscles is brought into contact with a copper wire which is touching the lumbar (loins) nerves, the frog's leg gives a convulsive movement, and that it does this every time the wires are brought into contact. Galvani knew that this convulsive movement was due to electricity, but he failed to see from what source the electricity was derived. He attributed it to electricity inherent in the frog's leg, and from this opinion he never wavered. Volta, however, fully recognising the importance of the discovery which Galvani had made, attributed the convulsive movement to its true cause, namely, electricity derived from chemical action; and this point he proved in the year 1800, by constructing what is known as the *Voltaic pile*. This pile consists of a series of discs of zinc and copper separated by wet cloth, and connected by two wires, one attached to each end of the series. When these wires are brought into contact a continuous current circulates through them, while a small spark is formed when the contact is broken; the zinc is dissolved, and this slow combustion of the zinc furnishes the requisite energy for the supply of the electric current. A new form of electricity, in the shape of a continuous current, was now available, and a new method of generating it, namely, chemical action. The Voltaic pile is, in fact, a true primary battery; and though it possesses nearly all the faults which a primary battery can possess, still, it none the less marks an epoch in the history of electricity which cannot but be looked upon as the point from which the science began to make rapid progress.

It was introduced into England in the same year, 1800, and so rapid was its development and improvement that four years later Humphry Davy was able to exhibit before the Royal Institution the true electric arc-light. After experimenting with numerous substances, he found that he got the brightest light when charcoal points were used. He took two charcoal rods, attached one to each end of the battery, and brought them into contact. A strong current now flowed through them, and on separating the points to the distance of about an eighth of an inch, an intensely bright light was formed between the points. This luminous space is known as the *arc*. This arc is composed of incandescent particles torn off from the carbon, and conducting the current across the gap. It is so hot that it can melt the diamond, while it vaporises gold and platinum. When the arc is formed in air the rods gradually wear away, the arc grows longer, until the distance between the points becomes too great, when the arc ceases. In our modern arc lamps a special mechanism is used to adjust the distance between the points.

The electric current heats everything through which it passes. If we take a carbon filament, and pass a sufficiently strong current through it, it will first be raised to incandescence, and then oxidised and quickly burnt away. But if we enclose the filament in a vacuum, and perform the same experiment, the result will be different. The filament will still be raised to incandescence: but, there being no oxygen present, it will not burn away; in fact, it will last for some thousands of hours, giving a bright light during the whole time that the current is being supplied to it. This latter type is known as the *incandescent lamp*. It usually gives from eight to twenty-candle power, while the arc light usually varies between five hundred and three thousand. We are thus able to obtain heat from the electric current, and, as might be supposed, the converse proposition also holds good—that is, *from heat properly applied to a suitable arrangement we can obtain electric currents.* The discovery of this fact was made by Seebeck about the year 1822. He found that, if he heated the point of contact of two dissimilar metals, and brought their other ends into contact with an

instrument capable of indicating the presence of a current, a current was actually generated in the circuit. This current lasted as long as the temperature of the heated junction was kept above that of the remainder of the circuit, and its strength depended within limits upon the difference of temperature of the two portions; its strength also depended upon the metals used. Bismuth and antimony form an admirable pair; the direction of the current through the heated junction being from bismuth to antimony. The necessary energy for the production of the current is supplied by the heat absorbed at the hot junction of the two metals, and the currents thus generated are known as *thermo-electric currents*. Much good work has been done by means of thermo-electricity, and even at the present day there are some telegraph lines being worked by means of it; but it cannot be said that the progress which has been made in it can in any way compare with that which has been effected in some of the other branches of the science. Suggestions have often appeared for the utilising of the spare heat absorbed by our common fire-grates, but up to the present no practical method has been devised for doing this in a satisfactory manner.

Very soon after the construction of the Voltaic pile it was discovered by Carlisle and Nicholson that if a current was passed through acidulated water, it decomposed some of the water into its constituent elements, oxygen and hydrogen. These elements were given off in the form of gas from the two surfaces—where the current entered and where it left the liquid—the oxygen from the former, and the hydrogen from the latter. On further investigation it was found that nearly all the solutions of metallic salts and acids behaved in a somewhat similar manner. This phenomenon has received the name of *electrolysis*, and the liquids which can be thus decomposed are called *electrolytes*. If a solution of sulphate of copper—blue vitriol—is subjected to electrolysis, the reaction which occurs is simple and interesting. Let us suppose that the current is being led into and out of the liquid by means of platinum plates—platinum is used for this purpose, as it is not acted upon by any acid, nor is it easily oxidised. When the current passes, the liquid is decomposed, and copper is deposited on the plate which leads the current out of the liquid. If this process is continued for a sufficiently long time, and the copper sulphate solution is not exhausted, a thick coating of pure copper will be deposited on the platinum plate. This coating of deposited copper will fit into, and fill up, the most minute inequalities which may exist on the platinum plate, and if it can be afterwards removed from it, it will be a reproduction, accurate to the most microscopic detail, of the plate on which it was deposited. The plates which lead the current into and out of the liquid need not necessarily be platinum. Any other substance through which electricity can flow, and which is not decomposed by the liquid, will answer quite as well, and the result will be exactly the same; so that all that is necessary, in order to obtain an electrotype from any article, or to plate it with a coating of copper, is to substitute it for the platinum plate, and subject it to the above-described process. In a similar manner gold, silver, platinum, nickel, iron, zinc, brass, etc., can all be deposited from their proper solutions, and, though each particular metal may require many special precautions to be taken, in order to insure satisfactory results, still the one leading principle just described governs the deposition of all. The electro-plating industry is necessarily the outcome of Volta's discovery, though the introduction of the dynamo-machine for the supply of large currents is fast driving the Voltaic cell out of the market for this particular purpose.

With the science of electricity in the condition just described, many attempts were made to utilise its properties for conveying signals from place to place; in other words, for conveying messages by means of *telegraphy*. It was possible to send a current along the metal line joining any two stations, but the difficulty which was experienced was to devise some apparatus by means of which the signal sent at one station could be translated into an intelligible form at the other. This is now done by means of electro-magnetism; but the connecting link between the electric current and the magnet had not been discovered at that time, and the principle of the electrolysis of water appeared to be the most suitable method for attaining the desired object. The two stations were connected by means of twenty-six wires, the ends of which dipped into separate vessels containing acidulated water. If an electric current was sent along any one of these wires it decomposed the water in the cup into which that wire dipped, and a quantity of gas was consequently evolved from that cup. If each of these cups represented a letter of the alphabet, it is clear that by sending currents along the proper wires, in the proper order, a word could be spelt and signalled between the stations. Telegraphy under these circumstances was not to be thought of, and before any simplifications could be introduced to reduce its expense, the discovery of electro-magnetism provided a more rapid, less costly, and less complicated means for doing the same thing in a much more satisfactory manner.

The above method is due to Sömmering, of Munich, and was proposed by him about 1811.

Some connection had long been supposed to exist between electricity and magnetism, and though many experimenters had searched for the connecting link, it was not till the year 1819 that it was discovered by Œrsted, of Copenhagen. He took a magnetic needle, and delicately pivoted it so that it took up a position pointing north and south. He then took a wire through which a current could be sent from a Voltaic cell, and held it directly above the needle in the direction of its length. On starting a current in this wire the needle was immediately deflected from the position it originally occupied, and turned through a certain angle depending upon the strength of the current, and it retained this position as long as the current flowed in the wire. If the wire had been placed immediately beneath the needle instead of above it, and the current sent in the same direction, the deflection would have been to the opposite side; but if, while the wire was in this position, the direction of the current had been reversed, the deflection of the needle would have been the same as in the first case. Combining these results it is clear that if a wire through which a current is flowing is carried above the needle, and then bent so as to pass back beneath it, both portions of the wire will tend to make the needle deflect in the same direction, and this tendency will be double that which either portion of the wire alone would exert. This principle was carried a step further by Schweigger, who wound a wire into the form of a coil and placed the pivoted needle at its centre. The force of the current on the needle was thus multiplied by the number of times which the wire was made to pass round the needle, *i.e.*, by the number of convolutions of the wire in the coil. This instrument is known as *Schweigger's multiplier*. This experiment clearly showed that some force, due to the existence of a current in the wire, was acting on the needle, and endeavouring to make it take up a position at right angles to the direction of the wire. This instrument of Schweigger's provided the first simple means for measuring the strength of a current, and was the embryo form of the galvanometer. Now for the first time we have a simple way of translating messages sent along a wire in the form of an electric current from one place to another. Let us suppose that we have one of Schweigger's multipliers at one end of a line joining two places. If a current is sent along that line and passed through the multiplier, it will deflect the needle in a certain direction, and if the current is passed through in the opposite way, the needle will deflect in the other direction. It now only remains to make up a code in which combinations of the deflections of the needle one way and the other shall represent particular letters of the alphabet, and we have a ready means of spelling out the words in accordance with this code, and of transmitting messages which shall be intelligible at the receiving station. The apparatus required for this system is inexpensive and simple when compared with that required for doing the same work by means of electrolysis, and the rapidity with which messages can be sent by a skilled operator is very much greater. A speed of forty words per minute can easily be obtained on a land-line by means of the hand, while a speed of four hundred or even five hundred words per minute is not considered high if the message is sent automatically. The distance which a message can be sent is practically unlimited, and a single line is all that is necessary to connect the two stations; in fact, two, four, or more messages can be sent along the same line in both directions at the same time by the apparatus which is now in use, without in any way interfering with one another; and what is more surprising still, these telegraph lines can also be utilised for conveying telephonic messages. Without any further great discoveries in electricity, telegraphy in a commercial form was undoubtedly possible, but it is equally certain that it never could have attained the prominent position which it now holds, had it not been for the discovery which almost immediately followed the one which has rendered Œrsted's name famous; this was a rapid and easy method for magnetising iron.

The first suggestion for utilising Œrsted's discovery for telegraphic purposes appears to have been made by Ampère in 1820. He proposed to use twenty-four pivoted needles, which were to be acted upon and deflected by twenty-four currents, each requiring a separate conducting wire. Steinheil, of Munich, seems to have been the first to construct a code or telegraphic alphabet, in which each letter is represented by some combination of two elementary signals, and in 1837 he pointed out the important fact that it is unnecessary to use two wires to convey signals; a single wire connected to the earth at both ends answers quite as well. He also invented a method of printing the message sent on a strip of paper, and to him is due the establishment of the first telegraphic system of communication on the Continent.

Many attempts had previously been made to magnetise iron and steel bars by passing currents in various ways through them, all of which failed; but Œrsted's grand discovery gave the clue as to the proper way to do it. In the same year that his discovery became known, both Davy and Arago

solved the problem of how to magnetise an iron or steel bar by means of a current. Instead of passing the current through the bar they wound a wire in the form of a spiral round it, and sent a current through this wire. The bar forthwith became a powerful magnet, and in the case of iron, when the current ceased, the bar immediately lost its magnetic properties. The magnets, which can be thus made, are far more powerful than any which can be made by any other known means, and what is of far more importance, they are perfectly under control, practically losing their magnetism at the same instant that the current stops. A magnet of this form is called an *electro-magnet*, and much credit is due to Sturgeon for the various improvements which he made in it. The value of these improvements will be better appreciated when we consider that there is scarcely a piece of electrical machinery at present in use which does not contain as one of its vital parts the electro-magnet in some form or other. Dynamo-machines, arc-lamps, motors, electric-bells, telephone transmitters and receivers, fire-alarms, and telegraphic receivers, all contain in a more or less disguised form the electro-magnet. It is an instrument so absolutely under control, and, when well designed, so capable of exerting great force, that we may look upon the time of its introduction as the date which marks the origin of electrical engineering proper. An electro-magnet is usually made by taking a coil or bobbin of wire through which a current is flowing, and introducing a piece of iron into it so as to form a core. The whole arrangement then acts in every respect like an ordinary magnet, but its strength depends upon the strength of the current and the quality of the iron. The direction of the current in the coil determines which end of the iron is to be the north and which the south pole. If the direction of the current is reversed, the polarity of the iron is reversed at the same moment.

It is found that either two north or two south poles will repel each other, while a north and a south always attract. Dealing with an electro-magnet, it can thus be made either to attract or repel the pole of an ordinary magnet placed near it, by making the current circulate in the proper direction through the coil. Can anything, then, be simpler than to construct a machine in which the pole of an ordinary magnet is placed near that of an electro-magnet, and is attracted and repelled alternately as the current is reversed in the coil? A reciprocating motion of the magnet is thus procured, which is precisely similar to that which takes place in the cylinder of the ordinary steam-engine; in a like manner, therefore, it can be made to do useful work by a suitable system of gearing. A machine of this kind is called a *motor*, and the principle just described applies to the construction of every type now in use; but it must be clearly borne in mind that an electro-magnet can in every case be substituted for an ordinary one, and usually with advantage. In modern machinery of this kind, the ordinary or permanent magnet has become nearly obsolete; the electro-magnet possesses such enormous advantages over it that it has almost entirely taken its place.

Jacobi, of St. Petersburg, constructed an engine of this kind in 1834, and five years later he propelled a boat by its means. Henry, in 1831, and Ritchie, in 1833, also constructed engines on the same principle, and though the attempt was made by many to construct one which would be a commercial success, still their efforts all met with the same fate—complete failure. There were many highly ingenious pieces of apparatus constructed, but they never got beyond the stage of being interesting working models. As a matter of fact, it would have been impossible for their efforts to have ended in anything but absolute failure. The reason is not far to seek. In order to construct a powerful electro-magnet, which is absolutely essential for a powerful machine, a strong current is necessary. This current was supplied by the consumption of zinc in the Voltaic cell; in other words, zinc was the fuel which was consumed or burnt up in the cell in order to supply the current to the motor. Let us compare it with the fuel which is consumed in order to supply steam to the steam-engine. A pound of coal is capable of doing about four times as much work, when burnt, as a pound of zinc, and zinc is about fifty times as dear as coal; therefore, for the same amount of money, we can get about two hundred times as much work from coal as from zinc. This is on the supposition that both methods of working are equally efficient; but it is found in practice that the electrical method of consuming the fuel has an advantage of about four to one, which leaves a final advantage of about fifty to one in favour of coal in the steam-engine against zinc in the cell. It was clearly impossible that the electric motor, under the then existing circumstances, could ever compete commercially with the steam-engine. This was the all-important point which the experimenters at that time did not realise. The one thing that was wanted in order to render the solution of the problem possible was a cheaper method for generating a current. This the progress of the science has now supplied by the evolution of the dynamo-machine; and the successful application of the motor in the industries has now become an accomplished fact.

PHOTOGRAPHY.—I.

BY T. C. HEPWORTH, F.C.S.

INTRODUCTION.

WITH the history of the art of photography we shall not attempt to deal in these pages; but will devote our attention to the practical side of the question, and shall endeavour to afford such practical instruction in photographic work as will enable anyone to pursue it, whether his object be

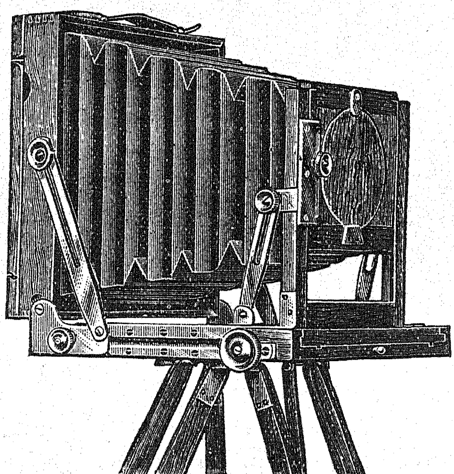


Fig. 1.

mere amusement, or whether he intend to adopt the art as a business. First we will describe the necessary apparatus employed in photography.

APPARATUS.

The photographic camera of to-day is based upon the old camera-obscura devised in the 16th century by the Neapolitan, Baptista Porta. It is probable that the first camera consisted of a dark room with a small hole cut in the window-shutter—like the rough arrangement adopted by our own Sir Isaac Newton when he dissected sunlight—and that this dark room had a screen placed within a few feet of the shutter to receive the inverted picture of the landscape outside.

But pin-hole photographs, however interesting they may be from an experimental point of view, are not really practicable for ordinary work. Nor is it reasonable to suppose that any person would care to take these pictures when such very much better ones can be obtained by the use of proper lenses.

The camera used by Daguerre, the eminent Frenchman to whom the first sun pictures are due, consisted of one box sliding within another with a lens fixed in the larger one. This instrument, it need hardly be said, was unnecessarily cumbersome, but it stood its ground till as late as the year 1854, when the first great improvement came in the introduction of the leather bellows camera body in lieu of the heavy wood. This at once gave the camera lightness and portability, and from this time improvements rapidly followed. Indeed it might almost be said that improvement in recent years has been over-elaborated: for the modern camera has too many movements; moreover, the lightness of the instrument has, for the sake of tourists, been carried so far that many of the cameras now sold will not stand much knocking about. The introduction of aluminium fittings instead of the heavy brass previously employed was a valuable improvement. Aluminium, bulk for bulk, is about one quarter the weight of brass, and when it is made to replace the latter in the metal parts of a whole plate camera, and also for the mounting of the lenses, it makes a difference of about one and a half pound in the total weight of the instrument.

But although we consider that modern cameras are many of them too complicated, there are certain movements which, in a perfect instrument, ought not to be dispensed with. One of the principal of these is the rising front, which consists of a plate of mahogany inserted between grooves in front of the camera, as shown in Fig. 1, upon which the lens flange is screwed. This rising front can be set at any height by means of a fixed screw with a milled head, but in some cameras it remains fixed in any position in which it may be placed by the action of spring clutches. Some cameras have a similar arrangement for giving a lateral movement to the lens, but this is of far less importance.

Another important adjunct to the photographic camera is the attachment of a swing-back. This will permit the groove which holds the ground glass screen, or the back containing the sensitive plate, to be inclined so that the surface can be fixed at an angle with the base of the instrument. It is also possible with most modern cameras to give this back a horizontal as well as a vertical swing, and occasionally this latter movement is of extreme use. In the annexed illustrations two forms of swing-back are represented. Fig. 2 is of a form very much older than that shown in Fig. 3, but for all this it is the better form, because the swing is from the centre and not from the bottom, as in Fig. 3.

As an example of the use of the vertical swing we may instance the extreme case of a sitting figure posed for a portrait in such a way that the head is at a distance of two feet further from the

lens than the feet. Any experienced photographer would of course avoid such a method of posing his sitter, and would do his best to keep the various parts of the subject more in one plane; so that we suppose, for the sake of illustration, an almost require to be drawn out farther than if we merely wanted to photograph the distant ones; but as we require to obtain images of both on the same plate, the horizontal swing-back will come to our assistance and we shall be able to get both into focus.

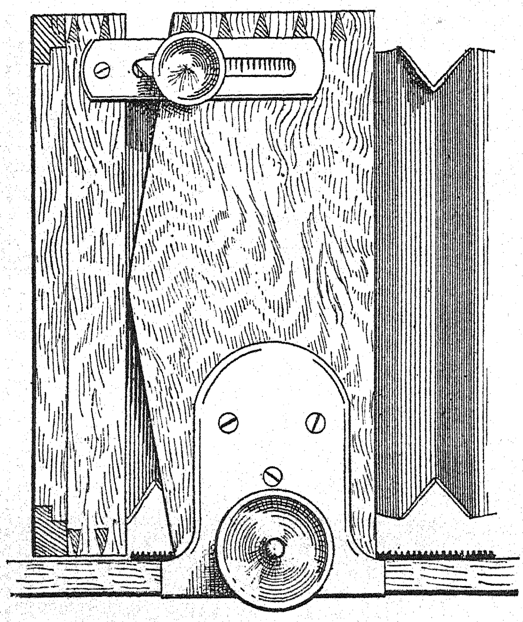


Fig. 2.

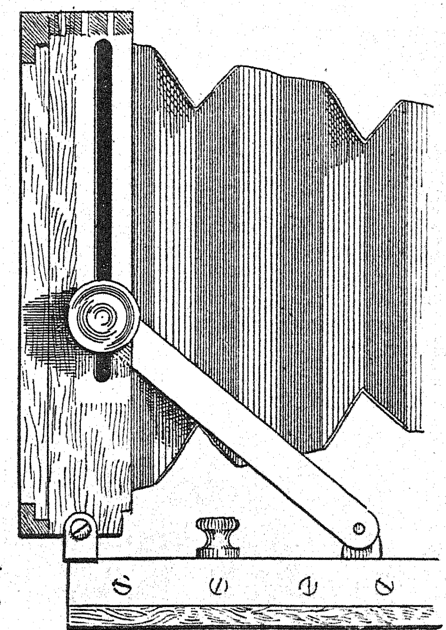


Fig. 3.

impossible case. It is obvious to the merest tyro that the nearer an object is to a camera the farther must the sensitive plate be from the lens, and *vice versâ*, so that in the case before us if the back of the camera be kept strictly vertical, either the head or the feet of the sitter must be terribly out of focus. But by help of the swing-back, we can so incline the plate that its top, upon which the image of the feet will be cast, is much farther from the lens than its lower part, upon which the image of the head is received. The same advantage is found in photographing an expanse of country where the foreground objects are necessarily much nearer to the lens than any of the other elements which go to make up the picture.

With regard to the side, or horizontal swing, it is found useful in such a case as the following. Let us suppose that a view is required, at some sea-side place, of a portion of the coast bordered by houses facing the beach, and that we want to take a view of the houses at one side with a glimpse of the sea at the other side. Now it is evident, that in order to focus the houses near at hand, the camera would

The swing-back acts the part, in fact, of a small diaphragm placed in the lens, and it is obvious that there must arise circumstances under which the insertion of such a diaphragm would be inconvenient. Thus it might be quite possible, and very probable, that in the case already quoted the beach would be crowded with a number of moving figures which could only be secured in the photograph by a very quick exposure; such an exposure would be out of the question if the various parts of the picture were brought into focus by the use of a small diaphragm instead of by the judicious employment of the swing-back.

There are two forms of camera bellows, one being square, and the other conical; we prefer the former, because it sometimes happens that if the other form be used while a wide angle lens is employed, the inside folds of the bellows will cut off some of the light which passes through the lens, thus robbing the picture of part of its foreground, sky, or side. The bellows should be long enough to enable the photographer to use long focus lenses, and this is one of the important points that must

be attended to in the choice of a camera. A quarter-plate camera should open out to about 14 inches and a whole-plate one to at least 2 feet, other sizes extending in proportion to the area of the plate which they are designed to take.

The camera chosen should be square, at least in cameras intended for out-door work, and it should have a reversible back, that is to say, the frame holding the ground glass screen should be so made that the screen can be placed, at will, horizontally with regard to its greater length, or vertically; so that a landscape, which has its greater length usually horizontal, can be taken at one moment, while a quick movement will place the screen into position to receive the image of such an object as a church tower, where the greater length of the picture will be vertical. Up to within recent times cameras were not made square, and the change between a horizontal or a vertical subject had to be made by unscrewing the camera from its stand, and attaching it once more by one of its sides.

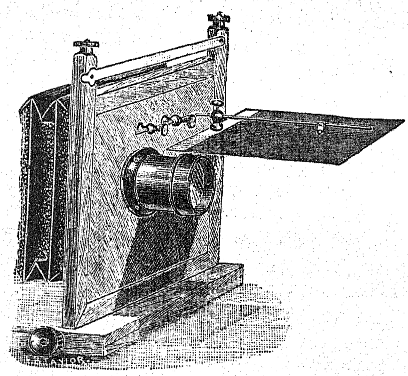


Fig. 4.

A useful attachment to the camera for out-door work is shown at Fig. 4. This is a metallic lens shade which can be quickly fastened above the lens at any required angle, and which can be carried on the top of the camera while travelling. When the sun is in front of the camera a shade of this kind is a necessity to prevent the light entering the hood of the lens. In the absence of some such contrivance the photographer is obliged to shield the lens with his hat—and very often in doing so cuts off part of his picture.

Cameras are usually provided with three double backs, each containing two sensitive plates. These are made in book form and perhaps represent the most generally convenient method of exposing plates in the camera which has yet been devised.

In expressing this opinion we do not lose sight of the fact that, for rollable films of celluloid, the ingenious roll holder devised by the Eastman Company, which will presently be described, cannot easily be surpassed. Other methods of changing plates have been devised, but they are of more interest in connection with hand cameras, to which we shall devote attention later on.

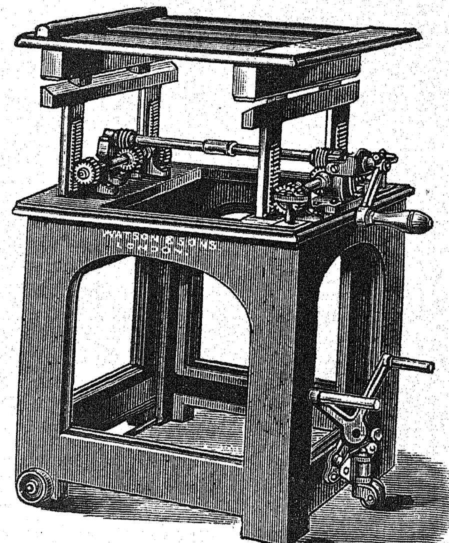


Fig. 5.

A camera intended for studio use is of much more solid form and a very much larger size than that generally used for out-door work. Of late years, indeed, the size of studio cameras has shown a tendency to increase, for large heads taken direct have recently come into vogue; there has also been a tendency to large portraiture generally, as is testified continually at our photographic exhibitions. A studio camera therefore requires a support of far more stable construction than the tourist form of instrument. Such a camera stand should easily move about the studio on wheels; it should have the property of being rapidly raised and lowered to different heights, so as to bring the lens into right position with regard to various sitters, and it should also provide for the camera being tilted when required. Such a stand lately introduced by Messrs. Watson, which fulfils all these requirements, is shown in the annexed woodcut (Fig. 5).

For out-door work the familiar tripod stand holds its own and is likely to continue to do so. Properly constructed, it is very firm in use, will bear a heavy weight, is light in weight itself, and will fold up into very small compass. A triangular piece of metal forms the tripod top, but in the latest form of camera this loose part is dispensed with by furnishing

the camera itself with a metal turntable, like that shown in the annexed figure (Fig. 6), to which the tripod legs can be attached direct.

A distinct advance in tripod heads is the form

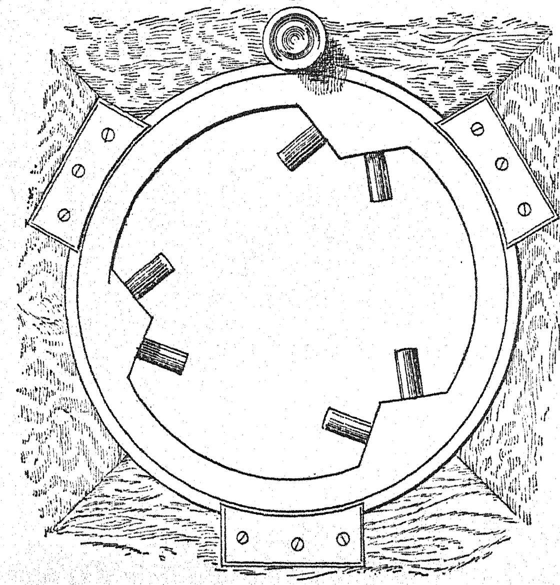


Fig. 6.

invented by Mr. J. J. Elmer, and made by Messrs. Newton (Fig. 7). The use of this top enables the photographer to level and clamp his camera rigidly, without troubling himself about the position of the three legs. The inventor describes the apparatus as "a plano-convex section of a sphere, working in an annular section of a sphere." The latter forms the tripod head, and the former the movable support for the camera. On the axis of this moving piece is a hollow screw, through which passes the fixing screw of the camera. On the hollow screw is a milled nut, by which the movable support is secured to the spherical ring in any required position. In the illustration (Fig. 6) the inner movable support is shown of solid wood, but an improvement has been introduced in the employment of aluminium, of which the rest of the apparatus is made. We may mention that Messrs.

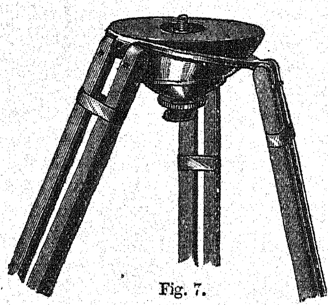


Fig. 7.

Newton manufacture a stand, fitted with this patent top, which is wholly made of aluminium, and which therefore combines extreme lightness with sufficient strength.

WATCH AND CLOCK MAKING.—I.

By David Glasgow,

Vice-President of the British Horological Institute.

WATCH MOVEMENTS.

The word "movement" is a technical term employed by watchmakers to denote the rough blanks or frames, wheels, pinions, etc., and does not mean, as the word would seem to imply, the machine in any stage of motion or action, but it certainly is the foundation on which the machine is built.

It may therefore be thought that technological lessons on watchmaking should begin with a description of watch-movement making, and a century ago that would have been necessary, as the early watchmakers made their own watches from the beginning to the finish; but it was found that by a division of labour the first part could be made by less skilled workmen than the men who completed the watch, and consequently at less cost. Movement-making therefore became a separate branch of watchmaking and almost a separate trade, as movement-makers were not watchmakers, and watchmakers could not make their own movements.

When these facts became acknowledged and acted upon, the natural advantages of Lancashire and the aptitude of the tool-makers and mechanics of Prescot secured for that locality the trade of watch-movement making, and until the last few years the movements of all the watches manufactured in London, Coventry, and Liverpool were made in Prescot and the districts adjoining it. The development of the factory system in England has made considerable changes in this, and now most of the factories make their own movements, at least those for the lower grades of watches. The movement consists of the rough mechanism of the watch, or those parts of it that could be made by machines more or less complicated, such as the plates or frames, cocks, bars, screws, wheels, and pinions, barrel, and fusee, if the watch is to have one, and now the chief part of the keyless works is considered a part of the movement. There were formerly a good many movement-makers, and as each one had his own notions of how a watch should be made, there was more variety than scientific proportions in the watches of different makers; some few watchmakers

insisted on having their movements made to their own caliber and proportions, and no doubt the suggestions made by these different makers produced what is now the best watch in the world, the three-quarter, or half-plate fusee watch.

But notwithstanding this and the recent diffusion of scientific knowledge, what has been called the typical English watch, the full plate, still holds a place in our manufactures. With all the obvious defects of this form of watch, quantities of full-plate watches with fusees are still made in England.

When the keyless winding was applied to full-plate watches, some of its defects were obviated, as the fusee with its thin chain and unsafe stopwork was abolished, but there are so many objections to this form of watch remaining that one can hardly account for its present existence, and still less for its being the model chosen by the American companies for the great part of their watches.

The primary consideration of a watchmaker should be the economical disposal of the space at his command, and unnecessary thickness in a watch is so obvious an evil that the opposite extreme has been occasionally reached: fashion had at one time demanded such thin watches that some of the old Swiss watches were practically toys.

The English ¾-plate fusee watch has been, and can be, made thoroughly sound with room enough everywhere, and yet elegant in shape, and when the going barrel was substituted for the fusee, watch-makers, or rather watch-sellers, insisted on the new form being similar to the old; the consequence of this has been that many of the English keyless watches are bad, from having mainsprings of such a substance that would be suitable enough for watches with a fusee, but that is too short and too thick for going barrels. The space in the back of the pillar plate, that suffices for the minute wheels, not being enough to receive the winding wheels, the movement for the going barrel, if of the same thickness from dial to top plate as that for the fusee, will have less space between the plates, and consequently a narrower mainspring. The barrel of a fusee watch is calculated to make three full turns on its arbors, and the spring does not require to be set up more than a few of the ratchet teeth; the going barrel on the other hand must make four turns on its arbor, and in order to get an approximate pull of the spring from first to last, it should be set up a full turn, therefore the necessity for a longer and broader mainspring. Some watchmakers have a boss on the top plate to enable them to get a deeper barrel and wider spring. They seem to forget that the height of one part of the plate may as well be the height of the whole, but this is of no consequence; but thick narrow mainsprings are a great evil, even in watches of the present day, and one that should be remedied if English keyless watches are to compete successfully with foreign ones that have not this defect.

WHEELS AND PINIONS.

Drivers and Followers.—Wheels and pinions are divided into two kinds, which are called drivers and followers. In watches and clocks the wheels are the drivers and the pinions the followers, except in the dial wheels, or motion work, the winding work of keyless watches, and some of the parts of complicated Swiss watches.

The main object to be aimed at in the gearing of wheels is to avoid "engaging friction," *i.e.*, friction which takes place through the teeth coming into action before what is called the "line of centres" (*i.e.*, a straight line drawn from centre to centre of wheels gearing together), and the reduction to a minimum of the drop or shake of the teeth. This object is best attained by the use of epicycloidal teeth for the drivers and hypocycloidal for the followers, and these are the only shaped teeth we have to consider.

An epicycloid is a curve generated by any point in the plane of a movable circle which rolls on the outside of the circumference of a fixed circle.

A hypocycloid is a curve generated by any point in the plane of a circle which rolls within the circumference of a fixed circle.

In Fig. 1, the curve G D, traced by any point D, in the circle D, rolling on the pitch circle A B C, is an epicycloid to A B C.

And the line G D, traced by the point D in the circle D which rolls within the circle G, is a hypocycloid to that circle.

If the generating circle is exactly half the diameter of the pitch circle within which it rolls, the hypocycloid traced will be a straight line radial to the pitch circle. This is a very usual and suitable shape for the acting part of pinion leaves. The pitch circles of wheels and pinions are the geometrical circles by which the calibers of watches and clocks are determined, and the bases from which the teeth are constructed.

The diameters of the pitch circles of wheels and pinions are inversely proportional to the number of revolutions made by them in a given time, and the velocity of wheels gearing together, with their teeth formed from the same sized generating circles, is the same as if their pitch circles rolled on one another without teeth at all, so that the number of teeth, of wheels, and of pinions is proportional to their pitch circles.

The epicycloid or acting part of the tooth of the driver should be outside its pitch circle, and the

hypocycloid or acting part of the tooth of the follower should be inside its pitch circle, in order to ensure a proper action.

The same sized rollers must be used for tracing

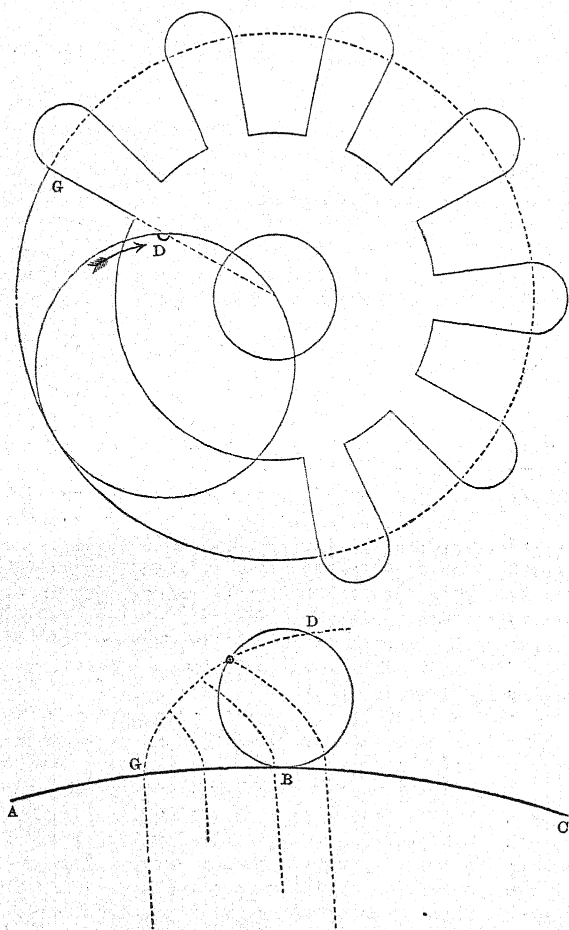


Fig. 1.—GENERATING CIRCLES FOR EPICYCLOID AND HYPOCYCLOID.

the epicycloids and hypocycloids of all wheels and pinions gearing together, when the curves traced will always intersect at the point D in the generating circle D; in whatever position the teeth may be with regard to one another, the hypocycloid will always be tangential to the epicycloid at that point of contact, the wheel and pinion will both travel at the same speed and with the smallest possible absorption of power, and the resistance will remain uniform throughout the lead, provided sufficiently high numbers are used to prevent all engaging friction.

Although teeth properly constructed in this manner are practically the nearest thing to perfection it is possible to attain, they have the disadvantage of a slight rubbing friction on one another in receding from the line of centres; and what are called involute teeth (*i.e.*, teeth having the acting curves of the shape described by any point in a string unwound off the circumference of a circle) were sometimes used in order to prevent this, and where several pinions geared with the same wheel, in the old French turret clocks and train remontoirs; but any advantage they possess in the saving of friction on the teeth is more than counterbalanced by the friction on the pivots caused by their obliquity and the squeezing pressure they produce, so that, although they are theoretically the perfect teeth, the surfaces rolling on one another throughout the contact without any rubbing friction, they are now looked upon as entirely useless.

Helical Teeth.—Another tooth which has been almost, if not quite, discarded, is the helical or helix (so called from the resemblance it bears to a spiral), which is a very good tooth in so far as with it the action takes place at the line of centres, but it is not suitable for watch or clock work, as it throws great end pressure on the opposite arbors.

Construction of Wheel Teeth. — In the event of two or more pinions of different sizes gearing with the same wheel, or with wheels of the same size as one another, the generating circle used in forming the teeth should not be larger than half the size of the smallest pitch circle, otherwise the pinion flanks would converge more than the radii and be too weak. In dividing off wheels and pinions for the teeth, the necessary freedom may be given by allowing one-fifth of the width of the leaf in the pinion for shake, the teeth and spaces in the wheel being equally divided. In the case of low-numbered pinions, as much as possible should be allowed for spaces, consistent with the strength of the pinion, in order to allow of a longer epicycloid to the wheel tooth, and so by getting a longer lead, to bring the action nearer to the line of centres, and thus avoid the greater engaging friction which would otherwise take place.

The addenda or points of the pinion leaves beyond the pitch circle are sometimes of semicircular and sometimes of an ogive form (the epicycloid of the tooth is commonly called the

ogive, from its resemblance in shape to the Gothic vault). Although theoretically addenda of any shape are unnecessary, the latter is a very good shape for the points of the teeth, as with it a safe depth is ensured, which is a matter of great importance in practice; and although high-numbered pinions would work very well for a time without addenda to the teeth at all, the depth would soon become too shallow from the wearing of the holes when not jewelled.

In sectoring the wheels and pinions of watches and clocks, it is found best to allow a shade more for the size of the wheel circle in proportion to that of the pinion, in order to secure a good "lead," as it is called, and to prevent any engaging friction or butting that might occur from the teeth not being quite accurate as to size or shape; the wheel by thus travelling a little faster than the pinion carries the pair or set of teeth that are in action so far beyond, that those approaching one another do not come in contact until they are at or near the line of centres.

Professor Willis, who, in his "Principles of Mechanism," has clearly expounded the theory of depths and the shapes of wheel teeth, has shown that no pinion of less than eleven leaves is entirely without engaging friction, though a well-sized pinion of ten comes into action so near to the line of centres that it is hardly perceptible, and therefore no pinion of less than ten should ever be used in machinery as a follower where it can be avoided, except the lantern pinion.

In gauging wheels and pinions round holes should be used as sizes where practicable, as the full diameter cannot be measured on a slide gauge if the teeth are not immediately opposite one another; and it should be remembered in depthing wheels and pinions that it is the *pitch* circles of the wheels and pinions, and not the full diameters, which are proportional to the number of teeth contained in them, so that allowance must be made for the parts beyond the pitch circles, which vary with the width of the teeth and the size of the generating circle used in tracing them.

In the train wheels of clocks and watches the full diameter is about 3·75 per cent. larger than the pitch diameter, and in high-numbered pinions the diameter is increased from 11·25 to 12 per cent., according to whether the addendum used is semicircular or epicycloidal. Thus, with a wheel of 60 and a pinion of 10 (in accordance with the rule given that the numbers of teeth of wheels and pinions are proportional to their pitch circles), the distance between the centres would be 70 and the diameters of the pitch circles 60 and 10 respectively; then the full diameter of the wheel would be 62·25, and that of the pinion 11·125, if its addenda were semicircular, or 11·2 if epicycloidal.

The flanks of wheel teeth are usually either parallel to each other or radial, and in order to free the addenda of the pinion, are cut within the pitch circle. The spaces are usually cut square to the bottom, but they should, where there is much stress upon them, be left rounded at the base of the tooth for strength, as in the great wheel of a modern English watch, which might otherwise strip its teeth in the event of a sudden strain taking place, such as the mainspring breaking or the winder being turned the wrong way.

Very small pinions should not be cut with radial flanks, or they would be too weak, and they should, where there is room, have the corners at the bases of the teeth left rounded as above. The teeth of all drivers, whether wheels or pinions, should be of epicycloidal form, and those of all followers of hypocycloidal.

Wheels and pinions that are to act alternately as drivers and followers should have their teeth as full as possible, of epicycloidal form, with the points taken off.

The pinions of all the better sorts of clocks, like those of watches, are cut in an engine, those of the common ones being made out of pinion wire (*i.e.*, wire drawn through a plate which forms the leaves, which are afterwards partially turned off to form the arbors), some of the best pinions being drawn first and finished afterwards in the engine.

Bevelled wheels are used in modern turret clocks for changing the plane of motion of the flies, hands, etc., and in the winding work of keyless watches. The angles made by the teeth with their arbors should be inversely proportional to the length of the arbors when produced till they meet, and every part of each tooth should converge to this point as if its acting surface were generated by a cone, as it should be theoretically. As in plain wheels and pinions, their pitch diameters are proportional to the number of teeth they contain.

In watch work bevelled pinions are seldom or never formed correctly, the teeth being formed by one cutter, which cuts the spaces out the same width throughout, instead of tapering them, as they should be, and consequently the teeth (even if they are cut at the right angle, which they seldom are) only touching at the extreme points; but as they are only used for the winding work, and are only in action for a short time, not much attention need be paid to this, the main object being to get a good depth and a smooth action, and this will be best secured by attention to the shape of the teeth and to their angle with regard to one another.

In keyless mechanism the rocking bar should always, where possible, be next to the plate under the great winding wheel, as this will allow of a larger diameter for the pinion, and any inequalities in the action through the teeth being cut the wrong shape, etc., will be less felt, and the wear on them will not be so great.

In Fig. 2 is shown a pinion E B F, the diameter of

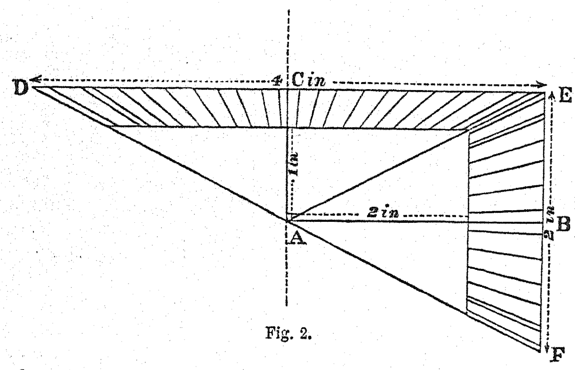


Fig. 2.

whose pitch circle is two inches, gearing with a wheel D C E, whose diameter of pitch circle is four inches; the arbors being produced till they meet at the point A. The line A B measures two inches, and the line A C one inch. Then the sum of the lines C A, A B : the sum of the angles C A E, E A B : : A B : C A E, or as C A : E A B. And in order to find at which angle the wheel ought to be cut, we have by trigonometry

$$\tan. CAE = \frac{CE}{CA} = \frac{AB}{CA} = \frac{2}{1} = 63^\circ\ 26';$$

$$\text{or, } \tan. BAE = \frac{BE}{AB} = \frac{AC}{AB} = \frac{1}{2} = 26^\circ\ 34'.$$

Or a sketch similar to Fig. 3 may be drawn to scale, and the angles measured off by means of a protractor.

Those who wish to study the whole theory of wheel teeth and their construction cannot do better than refer to the exhaustive treatise on the subject by Sir G. B. Airy, in Vol. II. of the "Cambridge Transactions."

The rules here laid down for the proper formation of the wheels and pinions of keyless watches (although quite correct) have been found so difficult to carry out, that the practice now followed in English watches is to gear the wheel and pinion at right angles to each other, and if the pinion is cut rather hollow towards the centre, and the teeth of the winding wheel sloped off on the under side, so as to be about half the thickness of the wheel at the points, they make a very smooth winding, and with the advantage that any wear brings the pinion closer to the wheel.

THE STEAM ENGINE.—I.

By Archibald Sharp, B.Sc., Wh. Sc., A.M.I.C.E.

Instructor in Engineering Design at the Central Institution of the City and Guilds of London Institute.

INTRODUCTION.

It has long been a well-known fact that if water be boiled in a closed vessel the steam generated may be caused to do mechanical work. What is frequently referred to as the first steam engine is due to Hero of Alexandria, and is of date 130 B.C. It consists of a hollow sphere (Fig. 1) supported on two tubular trunnions, which give communication between the interior of the sphere and a boiler. Two short bent pipes are attached to the sphere at the ends of a diameter at right angles to the axis of the trunnions. These short pipes are open at each end and therefore give communication between the inside of the sphere and the open air. On a fire being placed beneath the boiler, steam is formed and passes up through the tubular supports into the interior of the sphere. Thence it issues by the two bent pipes, and the sphere being free to rotate on the trunnions, the reaction of the escaping steam causes it to turn.

It is interesting to trace the development of the steam engine from this crude beginning, and to notice the improvements effected by Worcester, Savery, Newcomen, Watt, Trevethick, Stevenson, until we arrive at the forms in which we find it at the present day. Want of space prevents us giving a history of the steam engine. In these lessons we will describe the essential parts of typical modern steam engines, and explain, as clearly and fully as space permits, the principles involved in their working.

The description of the "boiler" in which the

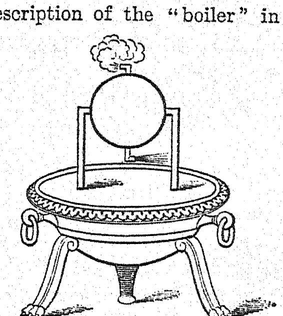


Fig. 1.

steam is generated will be given in a later lesson. Fig. 2 is a longitudinal section through the cylinder and valve chest of a steam engine of the most frequently occurring type; Fig. 3 is a transverse

section; Figs. 4 and 5 are side elevation with the valve chest cover removed and end elevation respectively. Steam from the boiler is admitted to the "valve chest" V C, by the steam pipe S P, and from there it passes through the steam port S_1 to the inside of the cylinder C, and presses on the piston P, which fits closely in the cylinder. When the piston has been driven to the left-hand end of the cylinder, the steam in the right-hand end is allowed to escape by the steam port s_1 through the back of the "slide valve" V to the "exhaust port" *e*, whence it escapes into the atmosphere or into the condenser. At the same time the slide valve uncovers the port s_2 and lets live steam from the boiler into the left hand of the cylinder. Thus the piston is driven from left to right, and similarly from right to left.

The motion of the piston is transmitted to the outside of the cylinder by a "piston rod" R, which passes through the "cylinder cover" C C. In order to prevent steam leaking from one side of the piston to the other "packing rings" P R are used. These are light split rings of cast iron or steel, which are sprung into grooves cut in the piston, and when the piston is in the cylinder they press outwards against the walls of the cylinder by virtue of their elasticity. The body of the piston should be a trifle smaller in diameter than the cylinder. To prevent steam leaking out of the cylinder where the piston rod passes through the cylinder cover, a "stuffing box" S B is formed on the latter. This box is filled with packing which is pressed tightly against the sides of the piston rod and of the stuffing box by the "stuffing gland" S G. The stuffing gland is screwed up tight by two studs and nuts. The packing in the stuffing box may be hemp steeped in tallow, for engines using low-pressure steam, say, up to 60 lb. per square inch. For steam of higher pressure, and therefore of higher temperature, "metallic packing rings" are used.

If the engine is to be used to turn a shaft, as is most usual, the end of the piston rod is attached by a pin joint to one end of a "connecting rod," the other end of the connecting rod being attached to a crank pin which moves in a circle.

The slide valve V is threaded, by means of the tube *t* formed on it, on to a "valve spindle" V S. The valve spindle has a reciprocating motion, which

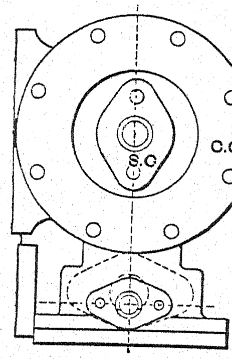


Fig. 5.

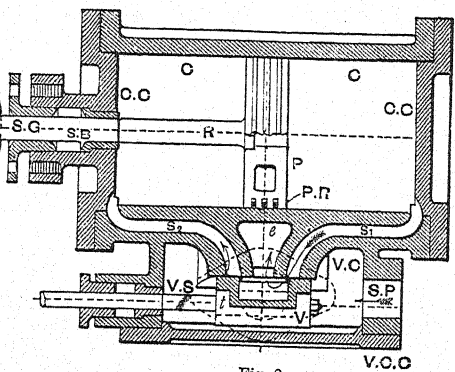


Fig. 2.

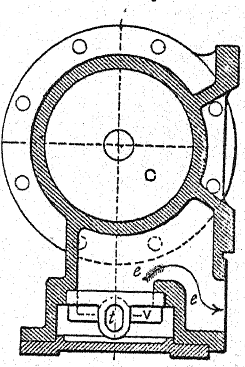


Fig. 3.

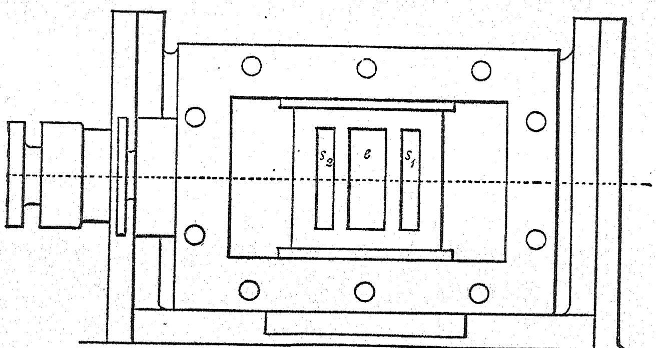


Fig. 4

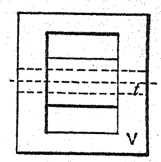


Fig. 6.

is communicated to the slide valve, and thus the opening and closing of the steam ports s_1 and s_2 is effected at the proper time. There is a stuffing

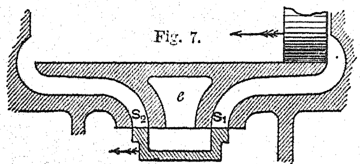


Fig. 7.

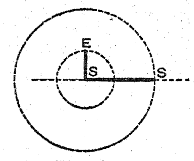


Fig. 12.

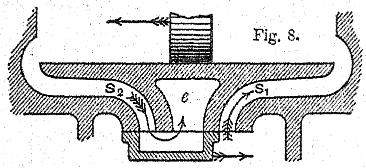


Fig. 8.

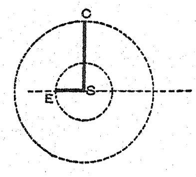


Fig. 13.

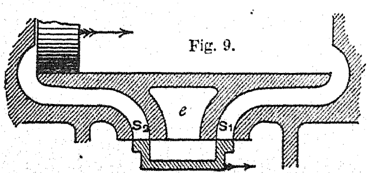


Fig. 9.

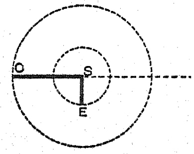


Fig. 14.

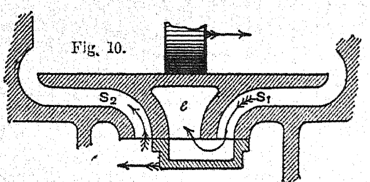


Fig. 10.

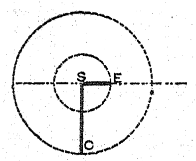


Fig. 15.

box and gland used where the valve spindle passes through the wall of the valve chest.

The steam ports are rectangular in cross section, as will be clearly seen by referring to Fig. 4. Fig. 6 is a view looking direct on the working face of the slide valve. The exhaust port e is led to the side of the cylinder: the arrangement is shown clearly in Fig. 3.

In Fig. 2 the piston and slide valve are both shown in their middle positions, but while the engine is working they are never in their middle positions at the same time. The outside edges of the slide valve are also shown overlapping the edges of the steam ports. In order to study the action of the slide valve, however, let us consider a slide valve with width of face just equal to the width of the steam port (Fig. 7). In Fig. 7 the piston is shown in its extreme right-hand position just beginning its stroke to the left. The slide valve should therefore just be uncovering the steam port s_1, and so allow the steam to pass from the boiler to the right-hand end of the cylinder. At the same time the port s_2 is allowed communication through the back of the slide valve with the exhaust port e, so that the steam in the left-hand end of the cylinder is free to escape. The slide valve, it is easily seen, should therefore be in its mid position and moving from right to left. Fig. 8 shows the piston in the middle of its stroke from right to left. The right-hand end of the cylinder is fully open to steam, while the left-hand end is fully open to exhaust. The slide valve is therefore in its position of maximum displacement to the left and is just about to begin its travel from left to right. Fig. 9 shows the piston at the end of its stroke from right to left, and just about to begin its stroke from left to right. The slide valve is again in its middle position and travelling from left to right, the steam supply to the port s_1 has just been cut off, and also the exhaust from port s_2; when the valve has travelled a small distance past the position shown, steam is admitted to the port s_2 and drives the piston to the right, and the exhaust port e is placed in communication with the port s_1, so that the steam in the right-hand end of the cylinder is allowed to escape. Fig. 10 shows the piston in the middle of its stroke from left to right, and the slide valve in its position of maximum displacement to the right. As the piston gets nearer the end of its stroke the slide valve begins to move towards the left, gradually cutting off the steam from the left-hand end of the cylinder and the exhaust from the right-hand end. When the piston reaches the end of its stroke to the right, the conditions are as shown in Fig. 7, and the cycle of operations is repeated.

We have now to study the means of giving the slide valve the motion described above. If the connecting rod P C in Fig. 11 be long in comparison with the crank S C, that is, if the angle the connecting rod makes with the centre line of the engine be small, the distance the piston has travelled from the right-hand end of the cylinder is approximately equal to d_2 C^1, C^1 being the projection on the centre line, of the crank pin centre C. And, with the same qualification, when the piston is at the middle of its stroke, the crank S C will be at right angles to the centre line S P.

Let the motion of the shaft be as indicated by the arrow (Fig. 11). Then if another crank S E of radius equal to half the required travel of the slide valve be fixed to the shaft one right angle in advance of the main crank S C, the slide valve may

be driven from this crank by means of a connecting link to the end of the valve spindle. Figs. 12, 13, 14, and 15 show the positions of the main and valve cranks corresponding to the piston and slide valve positions shown in Figs. 7, 8, 9, and 10 respectively.

In practice the crank pin at *e* is enlarged so

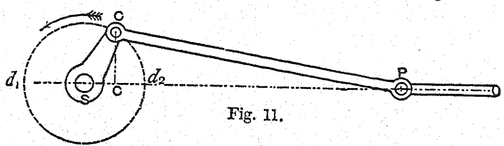


Fig. 11.

much that it embraces the shaft. In Fig. 16 *s* is the centre of the crank shaft *h h*, and *e* the centre of the slide valve crank pin. The crank pin is enlarged so that it includes the shaft *h h*, and it may then be made a circular disc with a hole bored in it to fit the shaft. The "eccentric," as the combination is now called, is of radius *s e*, and would give to any reciprocating piece moving in a straight line passing through the centre of the shaft a travel equal to twice the radius *s e*. The link connecting the eccentric with the end of the valve spindle is called the "eccentric rod."

The slide valve described above, that is one whose edges just cover the edges of the ports, is called the "normal slide valve." In practice several modifications are made; these will be explained in a future lesson.

In Figs. 12 and 14 the crank and connecting rod are in the same straight line, and consequently a pressure on the piston has no turning effect on the crank shaft. These crank positions are called the "dead centres." To carry the crank over the dead centres a heavy "fly-wheel" is keyed on the shaft: this heavy mass being set in motion cannot be stopped suddenly, and therefore suffices to continue the motion while the crank passes the dead centre. In double engines, that is where two engines drive the same crank shaft, they are arranged so that the two cranks are never on their dead centres at the same time. For example, in locomotives the cranks are at right angles. If three engines work on the same shaft, as in one arrangement of the modern marine engine, the cranks are set at an angle of 120° with each other.

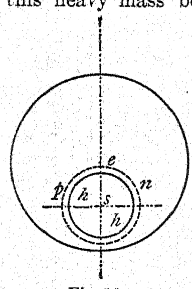


Fig. 16.

WORK, ENERGY, HEAT, PHYSICAL PROPERTIES OF GASES AND VAPOURS—THERMODYNAMICS.

A steam engine and boiler is essentially an apparatus by which heat is converted into mechanical work. In order therefore to study the action of a steam engine, we must have clear ideas about the nature of heat and work.

If a force acts against and overcomes a resistance, "work" is said to be done. The measure of the work is the product of the resistance, and the distance through which it is overcome. For example, if a weight of 1,000 lbs. be lifted vertically a height of 1 foot, the work done is $1{,}000 \times 1 = 1{,}000$ foot-lbs. Similarly, if 1 lb. be lifted vertically 1,000 feet the work done is 1,000 foot-lbs. Again, 100 lbs. to be lifted 10 feet requires the expenditure of $100 \times 10 = 1{,}000$ foot-lbs. of work. From these examples the student must be careful to see that "force" and "distance" must enter into the composition of "work," but "time" has no influence on it. The unit of work is therefore a unit compounded of the units of force and length; thus 1,000 foot-lbs. of work may be expressed as $1000 \times 12 = 12{,}000$ inch-lbs., or $\frac{1000}{2240} = \cdot 4464$ foot-tons, or $\frac{1000 \times 12}{2240} = 5\cdot 357$ inch-tons.

GRAPHIC REPRESENTATION OF WORK.

If a diagram (Fig. 17) be formed having the base O V equal to the distance, and O P at right angles to O V and equal to the force acting, the work done is represented by the area of the rectangle P V, proper attention being paid to the scales used to represent distance and force. Thus, if $o\,p =$ unit of force and $o\,v =$ unit of distance, then area of rectangle $p\,v$ represents unit of work. And the number of units of work done by force O P acting through distance O V is equal to the number of times the rectangle P V contains the rectangle $p\,v$.

This method of representation is specially useful when the force acting is variable, as, for example, the pressure of steam on the piston of a steam engine. When the piston has travelled a distance $o\,x$ (Fig. 19) from the beginning of its stroke, the steam pressure on 1 square inch of its surface is represented by $x\,y$. This pressure diminishes as the piston gets nearer the end of its stroke.

While the piston travels from x to x_1 the pressure falls from $x\,y$ to $x_1\,y_1$, but the fall of pressure is slight, and we may approximately consider the pressure to be constant and $= x\,y$, then the work done $= x\,x_1 \times x\,y$; that is, equal to the area of the rectangle $x\,y\,Y_1\,x_1$. Similarly while the piston moves through the space $x_1\,x_2$ the work done is equal to the area of the rectangle $x_1\,y_1\,Y_2\,x_2$.

Thus the work done per square inch of piston area during a stroke of the piston is the sum of a number of rectangles, and by taking the bases $x\,x_1$, $x_1\,x_2$, $x_2\,x_3$ of the rectangles small enough we

have ultimately the work done per square inch of piston area equal to the area of the figure O P A y B V.

Energy may be defined as capacity for doing work, and is measured by the amount of work done while the energy is being expended.

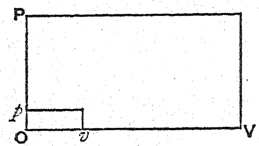


Fig. 17.

Thus: Energy exerted = Work done. The student with some knowledge of mechanics will recollect that—neglecting friction—the energy expended at one end of a machine is equal to the work done at the other end. Again, suppose a weight A be at a height x from the ground and be connected by a cord and pulley to an equal weight B resting on the ground, the weight A in descending to the ground can do as much work as is

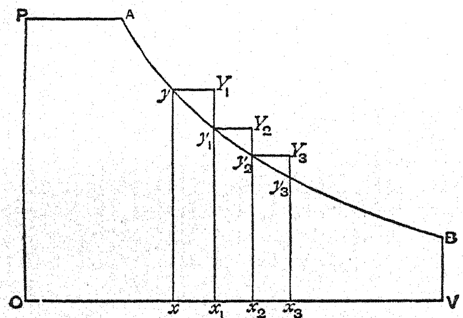


Fig. 18.

necessary to raise B through a height x. That is, the energy of A relative to the ground is the product of its weight and its height x above the ground. Energy, such as this, due to position is called "potential" energy. Again, a heavy fly-wheel can do a certain amount of work before coming to rest; the energy stored up in the fly-wheel is equal to the work it can do before coming to rest. This energy, due to motion, is called "kinetic" energy. A body may possess at the same moment both kinds of energy: a falling body possesses kinetic energy due to its actual velocity at the time under consideration, and potential energy due to its height above the ground at the same time.

The rate at which an agent does work is called the power of the agent. The unit of power used by engineers is the "horse-power," as defined by Watt. The performance of 33,000 foot-lbs. of work per minute, or of 550 foot-lbs. per second, is equivalent to one "horse-power." Electricians use another unit of power, the "watt," one "horse-power" being equal to 746 "watts."

Heat is a form of energy. It is a fact which is constantly noted in everyday life that heat can be produced by mechanical work. In sawing a piece of wood, filing a piece of metal, grinding a tool, and in fact in all processes where mechanical work is dissipated in friction, heat is produced. The converse fact, that heat may do mechanical work, is not so often demonstrated in everyday events, but still the examples are sufficiently numerous. When a fire is lit, the heat generated usually sets in motion the air in the neighbourhood. Coal mines used to be ventilated by having a great fire at the bottom of one shaft by which the heated air was free to ascend, while another shaft permitted the entry of fresh air to the mine, giving an example of the direct production of mechanical work from heat. Such a method was not very economical, and nowadays ventilation is effected by fans driven by steam engines. We shall see as we proceed with these lessons that in a steam engine the energy available is the heat given out by the combustion of the fuel in the furnace, and it is converted into mechanical work by the intervention of the boiler and engine.

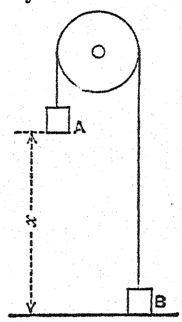


Fig. 19.

This theory as to the nature of heat was maintained by Newton, but not till Rumford and Davy at the beginning of this century performed some striking experiments on the production of heat by friction was the theory generally adopted by scientific men. It had been maintained before the beginning of this century that heat was a very subtle fluid which pervaded all bodies, that hot bodies had a larger quantity of this fluid than cold bodies, and that the conduction of heat from a hot body to a cold one was a flow of this fluid from the body having a larger supply to that having the smaller supply. "Caloric" was the name given to this fluid Count Rumford, in 1798, by boring a cannon with a blunt tool, generated heat sufficient to evaporate a large quantity of water. A little later Sir Humphry Davy melted two pieces of ice by rubbing them together. In both these experiments the only possible source of the heat produced was the mechanical work expended; they were the first severe blows at the material theory of heat. The mechanical theory of heat was firmly established by Joule's determination of the mechanical equivalent of heat. Before giving his result we must study a little more fully the effect of heat on substances and the measurement of heat.

DRAWING FOR ENGINEERS.—I.

INTRODUCTION.

THE lessons in this series are intended to give the student familiarity with the methods used in the drawing-offices of our best conducted engineering establishments, and it is hoped will be found useful as a text-book by apprentices and pupils in engineering drawing-offices and workshops, and by students in technical schools. The experienced draughtsman may find some portions useful for reference. These lessons are not intended to form a text-book on engineering design, and therefore there will be no attempt made to give an example from each class of machine detail, but the examples chosen will enable the industrious student to produce good, serviceable working drawings, that is, good drawings from the manufacturer's point of view. Engineers' drawings must be looked upon, not as works of art, but as means to an end, namely, the manufacture of the mechanism or structure delineated. The beginner is requested never to lose sight of this fact, and he must not hesitate to "spoil," what he might think, a pretty *drawing*, by making alterations, if the *design* is thereby improved. An artistic drawing may be very pleasing to look at, and, other things being equal, the neat draughtsman will be more valuable to his employer than the slovenly one, but the appearance of a working drawing must always be regarded as of secondary importance.

DRAWING INSTRUMENTS.

For working out an example in mechanical drawing, the learner should be provided with a drawing-board, T-square, two set squares, an engineer's drawing-scale, a set of drawing instruments, drawing paper and pencils, water colours, and brushes. Since the excellence of the work turned out depends greatly on the workman's skill in handling his tools, it seems advisable to devote some time to the description of the above instruments, and to indicate the best way of using them.

Drawing-Board.—The drawing-board should be made of well-seasoned yellow pine, those supplied by the best makers are made from wood which has had at least three years' seasoning. It should have two stout bars on the back, running at right angles to the fibres of the board. The four edges of the board should form an exact rectangle, and the beginner should test whether the angles are exactly right angles. It is usual to keep one edge of the drawing-board as the working edge, along which the stock of the T-square usually slides, the other three edges only being used when a line cannot be conveniently drawn from the working edge as a base. The working edges of the best drawing-boards are "ebony-edged." A board half imperial size, 23″ × 16″, will be found suitable for most of the examples given in this work.

T-*square.*—The T-square should have the blade screwed on to the top of the stock, so as to allow the set square to slide along the edge of the blade into the position indicated by the dotted lines

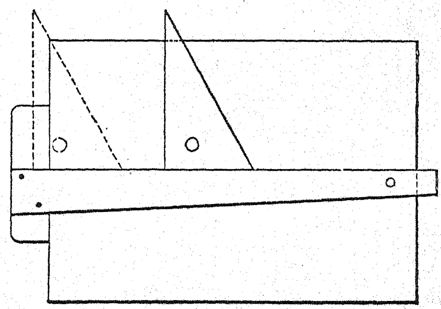


Fig. 1.

(Fig. 1). Two ebony pins fit exactly into holes bored through the blade and half-way in the stock, so that should the blade be unscrewed for the purpose of trueing up its edge, the pins ensure the stock and blade coming again into exactly the same relative position. The best T-squares have ebony edges. It is sometimes convenient to have a T-square with an alterable angle of blade. By far the best of those with which we are acquainted is Palmer's "Universal Drawing Edge," illustrated in Fig. 2. The large spring washer B ensures a large

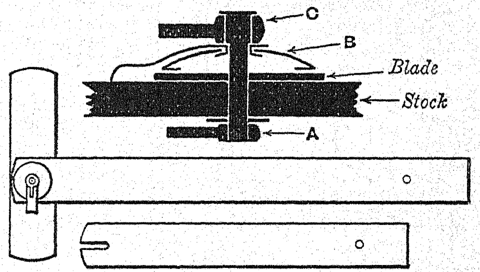


Fig. 2.

radius of contact between the blade and stock, so that when the nut C is tightened they are very securely fastened together. The tightness of the fastening can be regulated by the nut A, so that this T-square can be used as a parallel ruler.

In using the T-square the stock slides along the left-hand edge of the drawing-board, and is held by the left hand of the draughtsman until the blade is adjusted into the required position. Lines must always be drawn from left to right.

Set squares.—A 60° set square twelve inches long, and a 45° set square eight inches long, will be found most convenient for most engineering drawings. Plain wooden ones are the cheapest, but very soon warp; framed wooden ones last well, but are a trifle too thick for most draughtsmen's liking; those made of ebonite are perhaps the best. Transparent set squares have recently been introduced and seem to possess some advantages over those of ebonite. In using the set square for drawing vertical lines, its short edge should be placed against the edge of the T-square, so that the vertical edge is at the left, as in Fig. 1. Vertical lines must be drawn from the bottom towards the top of the drawing-board, and not in the contrary direction.

By aid of the 60° set square, the circumference of a circle can be easily divided into twelve equal parts (*b*, Fig. 3). By aid of the 45° square, the circumference of a circle can be divided into eight equal parts (*a*, Fig. 3). Fig. 4 shows the two set squares in position for drawing an angle of 15° and one of 75° with the horizontal. By reversing the 30° set square, and using the 45° as before, the dotted lines (Fig. 4) can be drawn. Thus by combining the 45° and 60° set squares, the circumference of a circle can be readily divided into twenty-four equal parts (*c*, Fig. 3).

Pencils.—The pencil used should be fairly hard. We find H H most generally useful, but for a very elaborate drawing a harder one will be better. The pencil should be sharpened to a "chisel point" not to a "round point," as when used for writing or freehand drawing. The wood should be removed by four flat cuts as shown in Fig. 5, and the width of the chisel must not be left the full width of the lead, but must be filed away at the sides until only about a third of the original width of the lead is left. Fig. 5 shows a properly sharpened pencil for mechanical drawing. With a very wide chisel point accurate drawing is nearly impossible, and with a round point the pencil gets blunted so quickly that fine lines cannot be drawn unless the point be very frequently resharpened. A smooth file 4″ long, or a small piece of sandpaper, will be found convenient for sharpening the point of the pencil. Leads for compasses are sharpened in the same way, but the chisel point may be a little narrower.

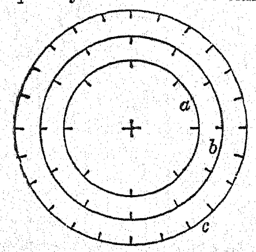


Fig. 3.

Compasses.—The compasses chosen should have a joint in each leg (Fig. 6), so that the end of each leg may be at right angles to the paper when describing a circle. If the foot of the fixed leg be not at right angles to the paper, the point will dig a small hole each time a circle is drawn, and where

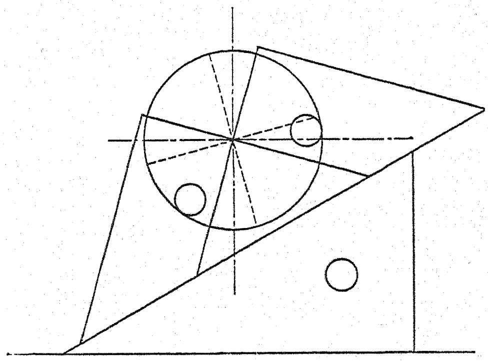


Fig. 4.

a number of concentric circles are to be drawn, the hole will be made large enough to disfigure the drawing. The point should be sharpened on an oil-stone to a conical point (Fig. 7), so that the point forms a pivot bearing for itself in the paper. Avoid having one or two sharp edges running down to the point, as in this case the compass point becomes a "rymer," and enlarges the hole in the paper with every circle drawn. Some draughtsmen prefer needle-pointed instruments. In using these, the needle should only project slightly from its holder, and the needle is pushed into the paper until the comparatively broad surface of the holder end rests on the surface of the paper. The compass pencil should be nearly perpendicular to the paper.

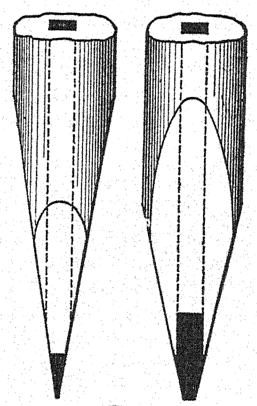


Fig. 5.

When using the pen compasses, special care must be taken to adjust the joint A (Fig. 6) so that both limbs of the pen touch the paper. If the compass be used as shown in Fig. 6, the result will be a line sharply defined on one side and blurred on the other (Fig. 8). This adjustment of the joint A must be made very carefully if it be desired to draw thick lines.

Spring bows are small compasses in which the radius is adjusted by a screw and a nut. Three-quarters of an inch is about the largest radius they

can take. In using them, the first finger of the right hand should be lightly pressed on the top of the shank, while the point of the leg rests on the paper, and the nut is adjusted by the thumb and

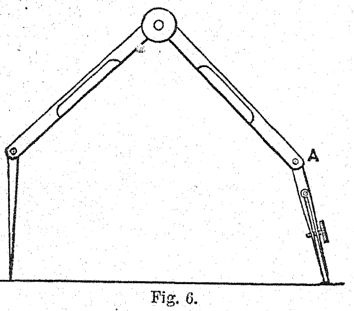


Fig. 6.

second finger. The circle is then drawn by rolling the shank between the thumb and first finger. On no account should both hands be used when manipulating spring bows.

Drawing-Scales.—The scale used must be one with all divisions brought to the edge, and should be twelve inches long. An engineer's drawing-scale made of box-wood, containing all the scales in general use, may be used. A set of paper scales, in which each strip of paper contains only one scale, has the advantage of clearness and simplicity, and the beginner is recommended to use these. Sharp's universal drawing scale (designed by the writer) contains on one side all the scales in general use by draughtsmen, and on the other a scale of inches divided into tenths and fiftieths at one edge, and a scale of millimetres at the other edge. It is fully divided throughout its length. The student who is also studying geometry and mechanics will find this perhaps the most convenient scale.

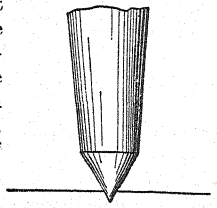


Fig. 7.

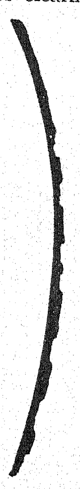


Fig. 8.

When marking off any distance, the scale is placed on the drawing and the pencil marks off on the paper the required length direct from the edge of the scale. *On no account should dividers be used for this purpose.* On a scale of full size, $\frac{1}{8}''$ is usually the smallest distance marked, but the student should have no difficulty in estimating $\frac{1}{16}''$, or even $\frac{1}{32}''$.

Ink.—For inking in drawings, Indian or Chinese ink must be used. The best is that sold in sticks, and is prepared for use by taking a few drops of water in a pallette and rubbing with the stick ink until a perfectly black emulsion is produced.

Liquid Indian inks are used, and, of course, they save the time and trouble of rubbing down from the stick. Most of the liquid Indian inks deteriorate in quality after exposure to the air. We have found Higgins' American Indian ink to be equal to, if not superior to, most others. It is supplied in bottles with rubber stopper and quill for filling the drawing-pen, and can be used without risk of soiling the fingers or instruments.

Water colours may be had in solid cakes or moist in collapsable tubes. The following are required for engineers' working drawings:—Crimson Lake, Prussian Blue, Payne's Grey, or Neutral Tint, Gamboge, Burnt Sienna, Burnt Umber.

Brushes are either of camel's hair or sable hair. Camel's hair brushes are cheaper than sable, but not so elastic. The student is recommended to have two sable hair brushes of the size known as "goose quill" and a larger brush of camel's hair. The brush, when moistened with water, should come to a sharp point.

Drawing-pins, india-rubber, and file for sharpening leads, and saucers for rubbing down Indian ink and for mixing colours must be provided.

Pencil Drawings from Dimensioned Sketches.—The beginner must take great care to produce a neat pencil drawing. Beginners are apt to hurry over the pencil drawing, thinking that when inking in they will put everything right. Our experience is that if a student begin to ink in a drawing not properly finished in pencil, he is sure to ink in some line that ought not to be, and which will have to be scratched out, so that the time spent on the drawing is greater than would have been the case if a little more time had been spent in properly finishing the pencil drawing. Again, in most drawing offices, the draughtsman leaves all his drawings in pencil, and from these tracings are made for the workshop, so that it is absolutely necessary for him to make clear pencil drawings. A good pencil drawing should have all its lines uniformly thick and uniformly dark.

The following rules should be carefully attended to in pencil drawing:—

1. When drawing a line whose ends are not determined in position, the pencil must be pressed very lightly upon the paper, so as just to make a visible mark. If one end of the line is already determined, it may be drawn firm at that end and get gradually lighter towards the undetermined end. These faint lines should be drawn a little longer than absolutely necessary.

2. If the ends of a line are determined by lines already on the paper, it should be drawn at once firm and even.

3. When the ends of a line drawn faint at first are determined, the part to remain on the paper should be gone over again with a firm and even pressure of the pencil.

4. The superfluous parts at the ends should be rubbed out as soon as convenient by a light stroke of the india-rubber.

Above all, the student must avoid having a number of faint lines without definite endings on his drawing-paper, as these will only confuse him in proceeding further with the drawing; but each part must be definitely finished before proceeding

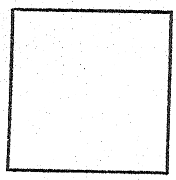


Fig. 9.

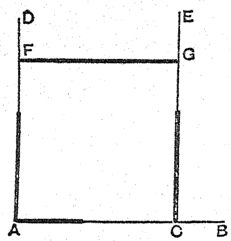


Fig. 10.

to another. If a line which has been firmly drawn with a hard pencil be rubbed out, a slight indentation is left on the drawing-paper; the student, however, had better risk having a few such indentations on his first drawings than err by over-timidity in drawing his lines firm.

The above rules will be applied in some of the following examples.

Example 1.—Draw a square of two-inch side. With the T-square draw a line A B firm at A but faint towards B (Fig. 10). Set the edge of the scale along A B, and mark off with the pencil the point C two inches from A. With the set square, draw the lines A D and C E faint towards D and E. Set the edge of the scale along A D and mark off A F = 2″. With the T-square draw the line F G, this line has its ends already determined by the lines A D and C E, and therefore it can at once be drawn firm.

The drawing will now have the appearance shown in Fig. 10.

The parts C B, F D, and G E are not required, and should now be rubbed out. The faint lines A C, A F, and C G should be made firm. The drawing is now finished, and has the appearance of Fig. 9.

Example 2.—Draw the pattern shown in Fig. 11. This example is an exercise on the accurate use of the 45° set square. The line 1 (Fig. 11) may be drawn with T-square 4″ long. The line 2 is drawn at right angles, and 3 at an angle of 45° intersecting at A. Similarly the lines 4 and 5 intersecting at B are drawn. Draw the line A B and check whether it is parallel to the line 1 or not. From O, the intersection of 3 and 5, project with the T-square the points C and D on lines 2 and 4 respectively. Draw lines 7, 8, 9, 10 with the 45° square, taking care that lines 7 and 8 intersect on line 1, and lines 9 and 10 intersect on line 6. From the points P, P, P, P, the intersections of 3 and 5 with 7, 8,

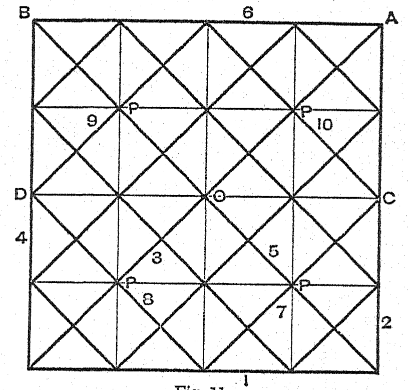


Fig. 11.

9, 10, project points on to lines 2 and 4. These serve as starting-points for another series of lines inclined 45° to the base line 1. The intersections of the thick lines (Fig. 11) inclined 45° should coincide with the intersections of the thin vertical and horizontal lines.

DYEING OF TEXTILE FABRICS.—I.

By. J. J. Hummel, F.C.S.

Professor and Director of the Dyeing Department of the Yorkshire College, Leeds.

FIBRES.

COTTON.*

1. *The Cotton-Plant.*—Cotton is the white, downy, fibrous substance which envelops, and is attached to, the seeds of various species of the *Gossypium*. After collecting and drying the cotton, the seeds are separated by the mechanical operation termed "ginning," and the raw cotton thus obtained is sent to the spinner. There are many varieties of the cotton-plant, the following being the principal:—

(1) *Gossypium barbadense* yields the Sea Island cotton, much prized on account of the great strength, length, and lustre of its fibres. It is grown in the North American States of South Carolina, Georgia, and Florida, and on the neighbouring islands of the West Indies.

(2) *Gossypium hirsutum* is grown in the States of Alabama, Louisiana, Texas, and Mississippi.

* *See* "Cotton Spinning."

(3) *Gossypium herbaceum*, grown in India, China, Egypt, and America, yields the Madras, Surat, and short-stapled Egyptian cotton, also some American cottons.

(4) *Gossypium peruvianum*, a native of South America, yields the long-stapled and much esteemed Peruvian and Brazilian cottons.

(5) *Gossypium religiosum* is grown in China and India, and yields the so-called Nankin cotton, remarkable for its tawny colour.

(6) *Gossypium arboreum* is a perennial tree which grows in India, and produces a good quality of cotton.

2. *Physical Structure.*—Under the microscope, cotton fibres appear as spirally twisted bands. Transverse sections show them to be flattened tubes. (*See* Figs. 1, 2, 3, *Cotton Spinning*, p. 13.)

A single cotton fibre is, indeed, an elongated collapsed plant cell. Sometimes broad ribbon-like fibres may be noticed, which are remarkably transparent. Their transverse section exhibits no central opening at all. They are, indeed, unripe fibres, in which no separation of the thin cell walls has yet taken place. They refuse to be dyed like ordinary ripe fibres, and appear occasionally as white specks in indigo- and madder-dyed calicoes; hence the name *dead cotton* has been given to them. The microscopic appearance of cotton serves to distinguish it from other vegetable and animal fibres.

3. *Chemical Composition.*—The substance of the cotton fibre is called *Cellulose.* The impurities present, amounting to about 5 per cent., comprise pectic acid, brown colouring matter, cotton wax, fatty acids (margaric acid), and albuminous matter. Pectic acid exists in the largest proportion.

In addition to these impurities, the cell wall of the raw cotton fibre seems to be covered with an exceedingly delicate membrane, or cuticle, which is not cellulose. If cotton, when under microscopical observation, be moistened with an ammoniacal solution of cupric hydrate, the fibre swells up under its influence, whereas the cuticle is unaffected and appears as band-like strictures or rings of various breadths. If a drop of sulphuric acid be then added, the cellulose separates as a gelatinous mass, which, on adding a drop of iodine solution, becomes coloured blue, whereas the cuticle is coloured yellow. The average moisture in raw cotton is about 8 per cent.

The chemical formula assigned to cellulose is $C_6H_{10}O_5$. It is closely allied in composition to starch, dextrin, and glucose, and is classed along with them as a carbo-hydrate. It is colourless, possesses neither taste nor smell, and has a density of about 1·5. If heated above 230° C., it becomes brown and begins to decompose. In contact with air it burns without emitting any very strong odour, a fact which may sometimes serve to distinguish it from wool and silk. It is quite insoluble in the ordinary solvents, but readily dissolves in an ammoniacal solution of cupric hydrate.

Action of various Agencies on Cotton.

4. *Action of Mildew.*—Owing to its comparative freedom from impurity, cotton may be stored for a long period without undergoing any change, more especially if it is bleached and kept dry. When, however, it is contaminated with added foreign organic matter, such as starch, gum, etc. (*e.g.*, in "finished" calicoes), and then exposed to a moist, warm atmosphere, it is very liable gradually to become tender or rotten. This is owing to the growth of vegetable organisms of a very low order, generally called "mildew." These fungi feed upon the starchy matters present, inducing their decomposition, and after some little time the cotton fibres themselves are attacked.

5. *Action of Frost.*—It has been erroneously supposed by some that wet calico is tendered when it is frozen. The idea probably arises from the fact that in their rigid state the cotton fibres are readily broken. A similar friable condition is obtained by excessive stiffening with starch or gum.

6. *Action of Acids.*—Cold dilute mineral acids have little or no action, but if allowed to dry upon the cotton they gradually become sufficiently concentrated to corrode and tender the fibre. The same corrosive action soon takes place if cotton impregnated with such acids is heated (or if it is exposed to hydrochloric acid gas). The process of "extracting" or "carbonising" woollen rags containing cotton (*i.e.*, destroying and removing the cotton), by means of sulphuric or hydrochloric acid, is founded on this fact.

The action of strong acids varies considerably according to the nature, concentration, and temperature of the acid, as well as the duration of its contact with the fibre.

Very concentrated *sulphuric acid* causes cotton to swell up, and form a gelatinous mass, from which, on the addition of water, a starch-like substance termed Amyloid may be precipitated. A solution of iodine colours this amyloid blue. An increased affinity for basic coal-tar colouring matters is said to be imparted to cotton by a treatment with acid, even when the acid is diluted to 84° Tw. (Sp. Gr. 1·42), although the physical aspect of the cotton then remains unchanged. Cotton completely disorganised by acid, and obtained as a fine powder, seems to contain one molecule of water more than ordinary cellulose, and the substance thus produced has consequently been termed Hydro-cellulose.

If the concentrated sulphuric acid is allowed to act for a longer time, the cotton dissolves with the formation of Dextrin ($C_6H_{10}O_5$); when the solution is diluted with water and boiled for some time, this dextrin is further changed into Glucose ($C_6H_{12}O_6$).

If cotton be heated with strong *nitric acid*, it is entirely decomposed, producing oxalic acid and an oxidised cellulose soluble in alkalies. By the action of cold concentrated nitric acid, or, better still, a mixture of strong nitric and sulphuric acids, cellulose is changed into so-called Nitro-cellulose. The physical structure of the cotton remains the same, but its chemical composition and properties are very much altered. The most highly nitrated compound is Pyroxylin, or Gun-cotton ($C_{12}H_{14}(NO_2)_6O_{10}$); it is very explosive, and insoluble in alcohol and ether. The less nitrated product forms the so-called Soluble Pyroxylin. Its solution in a mixture of ether and alcohol constitutes the Collodion of the photographer. Gun-cotton has an increased affinity for colouring matters, but no practical use has been made of the fact.

Artificial Silk-substitute, discovered by Chardonnet, is made by forcing a 6·5 per cent. collodion solution through a fine capillary tube immersed in a current of cold water flowing in the direction of the collodion as it issues from the tube. In contact with the water the collodion solidifies, and the fibre thus formed is at once reeled. A subsequent treatment with dilute nitric acid and also ammonium phosphate solution deprives the fibre of excessive inflammability. The fibre is similar in appearance to boiled-off silk, and may be dyed after the manner of silk, but at low temperatures only.

Strong *hydrochloric acid* behaves towards cotton like sulphuric acid, but its action is less energetic.

Solutions of *tartaric*, *citric*, and *oxalic acids* have no destructive action on cotton if it is simply steeped in the liquid; but if cotton saturated with a solution containing 2 per cent. of any of the above acids is dried and heated for an hour to 100° C., it becomes slightly tendered.

Acetic acid has, under ordinary circumstances, no perceptible action on cotton.

7. *Action of Alkalies.*—Weak solutions of *caustic potash* or *soda*, when used cold, have ordinarily no action on cotton, although long-continued and intermittent steeping and exposure to air tender the fibre. Cotton may even be boiled for several hours with weak caustic alkalies, if care be taken that it remains steeped below the surface of the solution during the whole operation, but otherwise it is very liable to become rotten, especially if the exposed portions are at the same time under the influence of steam. Such exposure is to be guarded against during certain of the operations in bleaching cotton fabrics. The tendering action is probably due to oxidation. It is worthy of note that the disorganised fibre (oxy-cellulose) possesses an increased attraction for basic coal-tar colouring matters.

The action of *strong* solutions of caustic potash or soda is very remarkable. If a piece of calico is steeped for a few minutes in a solution of caustic soda, marking about 50° Tw. (Sp. Gr. 1·25), it assumes quite a gelatinous and translucent appearance; when washed free from alkali, it is found to have shrunk considerably, and becomes much closer in texture. If a single fibre of the calico thus treated be examined under the microscope, it is seen to have lost all its original characteristic appearance; it has no superficial markings, and is no longer flat and spirally twisted, but seems now to be thick, straight, and transparent. A transverse section shows it to be cylindrical, while the cell walls have considerably thickened, and the central opening is diminished to a mere point (Fig. 1). Many years ago a Lancashire calico-printer, John Mercer, discovered that calico treated in the above manner was not only stronger than before, but had also acquired an increased attraction for colouring matters, hence cotton thus treated is said to be mercerised. The process, however, has never been adopted in general practice.

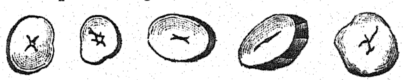


Fig. 1.—Transverse Sections of Cotton Fibre after Treatment with Caustic Soda.

Caustic ammonia and solutions of the *carbonates of potash*, *soda* or *ammonia*, *silicate of soda*, *borax*, and *soap* have, under ordinary circumstances, practically no action on cotton.

8. *Action of Lime.*—Milk of lime, even at a boiling heat, has little or no action upon cotton so long as the latter is steeped below the surface of the liquid, but if it is at the same time exposed to the action of steam, it becomes much tendered by oxidation of the fibre. Such exposure must be avoided in cotton-bleaching.

9. *Action of Chlorine and Hypochlorites on Cotton.*—Cotton is quickly tendered if exposed to moist *chlorine gas*, especially in strong sunlight. Solutions of *hypochlorites* (bleaching-powder, etc.) tender cotton more or less readily, according to the strength and temperature of the solutions and the duration of their action. Even a very weak solution of bleaching-powder will tender cotton if the latter be boiled with it; but when used cold, the destructive action is inappreciable. If a piece of

calico is moistened with a solution of bleaching-powder at 5° Tw. (Sp. Gr. 1·025), then exposed to the air for about an hour, and washed, it will be found to have acquired an attraction for basic coal-tar colouring matters similar to that possessed by the animal fibres. This remarkable change is due to the action of the hypochlorous acid liberated by the carbonic acid of the air. The cotton is thereby oxidised, and becomes chemically changed to so-called Oxy-cellulose.

10. *Action of Metallic Salts.*—Under ordinary circumstances, solutions of neutral salts have no action on cotton; with acid salts the effect is similar to that of the free acids, though less marked. If cotton is impregnated with solutions of the salts of the earths and heavy metals, then dried, and heated or steamed, the salts are readily decomposed; a basic salt is precipitated on the fibre, and the liberated acid affects the fibre according to the nature and strength of the salt solution employed.

The application of the so-called "topical" or "steam colours," and the "mordanting" process employed by the calico-printer, are based upon the above facts.

Cotton canvas impregnated with ammoniacal solution of cupric hydrate, squeezed and dried, becomes green-coloured, and coated with a varnish of amorphous cellulose. The product is known as "Willesden canvas," and being rot and rain proof, is useful for tents, etc.

11. *Action of Colouring Matters.*—With the exception of Indigo, Turmeric, Safflower, the Benzidine colours, and a few others, colouring matters are not directly attracted from their solutions by the cotton fibre, hence special means of preparing it to receive such dyes have to be adopted, viz. the "mordanting" process, to which fuller reference will be made subsequently.

FLAX, JUTE, AND CHINA GRASS.

12. *Flax-plant.*—The linen fibre consists of the bast cells of the flax-plant *Linum usitatissimum* (Fig. 2), which is cultivated in nearly all parts of Europe.

To obtain good fibre, the plant is gathered before it is fully matured—namely, when the lower portion of the stem (about two-thirds of the whole) has become yellow. At this stage the plants are carefully pulled up.

The flax is at once submitted to the process of "rippling," in order to remove the seed capsules. This operation is performed by hand, by drawing successive bundles of flax-straw through the upright prongs of large, fixed iron combs, or "ripples." If the pulled flax has been dried and stored, the removal of the seeds is usually effected by the seeding-machine, which consists essentially of a pair of iron rollers, between which the flax-straw is passed.

13. *Retting.*—The most important operation in separating the fibre is that of "retting," the object

Fig. 2.—A, Flax Plant; B, Flower; C, Fruit.

of which is to decompose and render soluble by means of fermentation, as well as to remove, certain adhesive substances which bind the bast fibres not only to each other, but also to the central woody portion of the stem, technically termed the "shive," "shore," or "boon."

The usual modes of retting are as follows:—

(1) *Cold-water retting.* This may be carried out either with *running* or with *stagnant* water.

(2) *Dew retting.*

Cold-water Retting.—The best system of retting in *running water* is said to be practised in the neighbourhood of Courtrai, in Belgium, where the water of the sluggish river Lys is available. The bundles of flax-straw are packed vertically in large wooden crates lined with straw. Straw and boards are afterwards placed on the top, and the crate thus charged is anchored in the stream and weighted with stones, so that it is submerged a few inches below the surface. In a few days fermentation begins, and as it proceeds, additional weight must be added from time to time, in order to prevent the rising of the crates through the evolution of gas. As a rule, after steeping for a short period, the flax is removed from the crates, and set

up in hollow sheaves to dry; it is then repacked in the crates, and again steeped until the retting is complete. According to the temperature, quality of flax, etc., the duration of the steeping may be from ten to twenty days. The end of the process must be accurately determined by occasionally examining the appearance of the stems, and applying certain tests. The flax bundles should feel soft, and the stems should be covered with a greenish slime, easily removed by passing them between the finger and thumb; when dried and bent over the forefinger the central woody portion should spring up readily from the fibrous sheath. If a portion of the fibre is separated from the stem and suddenly stretched, it should draw asunder with a soft, not a sharp, sound.

When the retting is complete, the flax is carefully removed from the crates and set up in sheaves to dry.

Retting in *stagnant water* is the method usually adopted in Ireland and Russia. The flax in this case is steeped in ponds, situated near a river if possible, and provided with suitable arrangements for admitting and running off the water.

This mode of retting is more expeditious than when running water is employed, because the organic matters retained in the water very materially assist the fermentation; there is, however, always a danger of "over-retting," that is, the fermentation may become too energetic, in which case the fibre itself is attacked and more or less weakened. This danger is minimised by occasionally changing the water during the steeping process.

After retting in stagnant water, the flax is drained, then thinly spread on a field; it is left there for a week or more, and occasionally turned over. This process is termed "spreading," or "grassing." Its object is not merely to dry the flax, but to allow the joint action of dew, rain, air, and sunlight to complete finally the destruction and removal of the adhesive substances already alluded to.

The quality of the water employed in retting is of considerable importance; pure soft water is the best, calcareous water being altogether unsuitable.

Dew retting simply consists in spreading the flax on the field and exposing it to the action of the weather for six or eight weeks, without any previous steeping in water. Damp weather is the most suitable for this method, since all fermentation ceases if the flax becomes dry. Dew retting is practised largely in Russia and in some parts of Germany.

The *warm-water retting* of Schenck, the *chemical retting* of Baur, and the *steam retting* of Dogny, have not been able to supplant the older processes just described.

14. *Chemistry of Retting.*—Experiments by Kolb indicate that the adhesive matter which cements the flax fibres together is essentially a substance called *pectose.* During the retting process the fermentation decomposes this insoluble pectose, and transforms it into soluble *pectine,* and insoluble *pectic acid.* The former is washed away, the latter remains attached to the fibre.

15. *Breaking.*—The next process is to remove the woody centre from the retted and dried flax, after which the fibres must be separated from each other. The various mechanical operations for effecting this comprise "breaking," "scutching," and "hackling."

The first operation aims at breaking up the brittle woody centre of the flax into small pieces, by threshing it with an indented wooden mallet, or by crimping it with a many-bladed "braque." The operation is now extensively done by machinery, the flax being passed through a series of fluted rollers.

16. *Scutching.*—In this process handfuls of the flax are beaten with a broad wooden scutching-blade; the broken particles of woody matter adhering to the fibres are thus detached, and the bast is partially separated into its constituent fibres. Scutching is also performed by machinery. The waste fibre obtained is called "scutching tow," or "codilla."

PRACTICAL MECHANICS.—I.

By R. Gordon Blaine, M.E.

Assoc. M. Inst. C. E., &c.; Senior Demonstrator and Lecturer on Mechanical Engineering and Applied Mechanics at the City and Guilds of London Technical College, Finsbury.

INTRODUCTION — COMPOSITION AND RESOLUTION OF VECTOR QUANTITIES—GRAPHIC METHODS.

The subject of Practical Mechanics is of great importance to all who wish to study Engineering in any of its branches, or who wish to be acquainted with the practical applications of the laws of force and motion. Until recently the subject has been, to a large extent, neglected, except by students who were obliged to take it up in order to pass certain university or other examinations. Books on mechanics were written, usually, as aids to those students, and hence a certain class of problems were repeated, and became crystallised in the text-books. Those problems were usually of a very unreal nature, and unlike the questions which come before the practical workman or engineer; hence the text-books and the subject were alike neglected by the practical man. Within recent years a few writers, such as Professor Perry and others, have recognised the fact that there exists a large class

of very intelligent *practical* students who wish to study such a subject as this for the sake of the actual working knowledge which they may derive from that study, and who look at all questions from the point of view of PRACTICAL UTILITY. Mere geometrical problems, which have only a remote connection with the subject of mechanics—such as many of the problems to which I have alluded as given in the earlier text-books—offer no attractions to them. Many of these students possess only a limited knowledge of mathematics, nor is it necessary that they should possess more in order to gain a practical knowledge of the fundamentals of the subject. The best recent writers have recognised this fact, and also the fact that these students, as a rule, possess a large fund of common-sense, together with considerable experience of the action of mechanical laws, which may be taken advantage of, though the laws themselves in their commonly enunciated form are unknown to them. The practical man readily gets hold of a great principle, like the "law of work," and if we can base our proofs and arguments, to a considerable extent, on such a law, so much the better as far as his progress is concerned.

I hope in these lessons to bring before the student, whom I shall suppose to be of a practical turn of mind, some of the more important facts and laws of mechanics, especially in regard to their useful applications.

I shall not assume any large amount of mathematical knowledge on the part of the reader. A knowledge of the ordinary rules of arithmetic, and the ordinary signs of algebra, such as $+$, $-$, $\times$, $\div$, $\sqrt{}$, $=$, etc., together with the operations they symbolise will be sufficient. It will also be necessary to understand the meaning of a simple equation, but this knowledge, if not already possessed, can easily be acquired by a few hours' study of the lessons on Arithmetic and Algebra in the NEW POPULAR EDUCATOR.

Mechanics is often defined as the subject which deals with force as applied to material bodies. This would naturally lead us to a definition of *force*, but no definition we could give would be of much service at this stage. The intelligent reader *knows* what is meant by a force—probably he thinks of it as a push or a pull. It will not simplify matters to tell him that force is "that which moves or tends to move matter," *i.e.*, is that which produces *motion* or *strain* of, or in, material bodies. This and other definitions will be of greater service later on. For the present it will be sufficient to think of forces and other quantities of this nature—with which we have so much to do in mechanics—as belonging to the great class called *vector quantities*, and we shall, without defining each separately, proceed to explain how to deal with such quantities. What is a "vector quantity?" Any quantity which is completely specified when its magnitude, direction, and sense or sign are given is a vector quantity. A force at a given point, a velocity, or an acceleration, will be completely specified if the magnitude, direction, and sense of the quantity are given, and each can be completely represented by a straight line; the *length* of the line showing the *amount* of the velocity, etc.; the direction of the line the parallelism of the quantity, and an arrow-head on the line its sense or sign. Thus a velocity of 20 feet per second in a given direction at a given point would be represented by a line of 20 units long drawn in the proper direction at that point, or at a point representing the given point, and an arrow-head on the line would show whether the velocity is *away from* or *towards* the point. This last constituent is sometimes—though less neatly—shown by the sequence of two letters, which are placed one at each end of the line.

There are other quantities, in dealing with which we are concerned merely with their *magnitude*, such quantities as, for instance, a sum of money, or a specified volume of any given material. Quantities of this kind, which require only to be specified in so far as regards their magnitude, and which, therefore, can be represented by mere numbers, are sometimes called *scalar* quantities. Such quantities are very simply dealt with. If, for instance, we wish to find the sum of any number of them—of the same kind—we have only to add together the numbers expressing their several magnitudes, and the work is done. Vector quantities, on the other hand, are much more complicated altogether, but they are also much more frequently met with in mechanics than their simpler brethren. To add two or more vector quantities we have to use what is known as the "parallelogram," "triangle," or "polygon of forces." Formerly, we stood up for our old friend the parallelogram, and two vector quantities, say two forces, of 10 and 7 units respectively, acting as shown in Fig. 1, were "compounded," or added by measuring off along A B a distance equal to 10 units, along A C a distance of 7 units, constructing on these two lines, as adjacent sides, a parallelogram A C D B, the diagonal A D of which represented the sum or resultant of the given forces to the scale previously chosen for the remainder of the figure. This seems all plain and simple, but it should be carefully noted that this construction is only correct if both the forces (or velocities) act *towards*, or both *away from* the point A. Thus, in Fig. 2, two forces, similar to those in Fig. 1, are given, except that one of the

forces, A B, acts this time *towards* the point. If the parallelogram is constructed as before, there will be a difficulty in deciding the proper direction to give to the arrow-head of the diagonal, in fact,

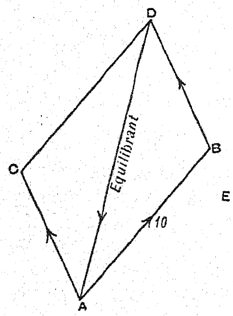


Fig. 1

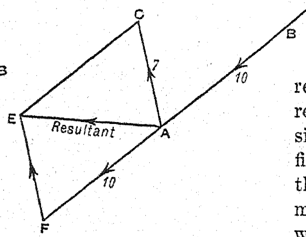


Fig. 2.

the construction will fail in this case. It will be necessary to produce one of the lines, say A B, on the other side of A, then measure off A F = 10 units, and proceed as before, the forces now both acting away from the point. The student is very liable to fall into a mistake in this matter, and hence the "triangle of forces" is adopted instead of the parallelogram. This triangle would be similar to A B D in Fig. 1, and to A F E in Fig. 2, and would be more conveniently constructed at some distance from the point at which the forces act. If, then, three forces or other vector quantities act at a point, and are in equilibrium, they will be parallel and proportional to the sides of a triangle, and the arrows on these sides will be concurrent. Any side of such a triangle will represent the *equilibrant* (meaning that which with the others produces equilibrium) of the other forces, and will represent their *resultant* if its arrow is turned the other way.

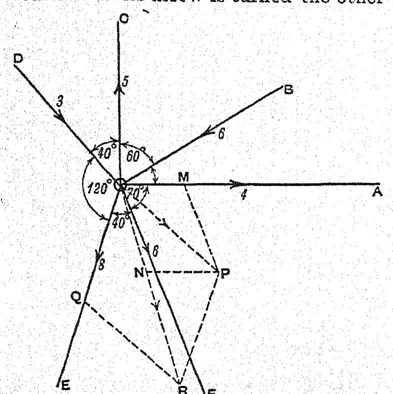


Fig. 3.

The principle can be extended to any number of forces acting at a point. Thus, in Fig. 3, forces of 4, 6, 5, 3, 8, and 6 lbs. are represented as acting at the point O, along the lines O A, O B, O C, O D, etc., respectively.

The resultant of these forces could be obtained by the old method, *i.e.*, by finding the resultant of the forces in O A and O F by the parallelogram rule, then the resultant of this resultant and the force in O E, and so on, as before.

But this is tedious: it is much simpler to construct a polygon, as in Fig. 4, each side of which represents one of the given forces to scale, the resultant being represented by the last or closing side, shown dotted in the figure. The order in which the forces are taken does not matter, but accuracy in the work is more easily attained if no two consecutive sides intersect at too acute an angle. I have here referred only to forces, or other vectors, acting at one point and in *one plane*. If the forces act at one point but *not* in one plane, the rule is still true, that if they are in equilibrium a closed polygon can be constructed with sides representing the several forces. The polygon in this case cannot very well be represented in a drawing, but may be constructed of wire. It will be of an awkward shape, and is called a *gauche* polygon. It is evident, however, that the elevation and plan of this polygon are both closed polygons, and if the forces are not in equilibrium—and hence the polygon *not* closed—the elevation and plan of the closing side can easily be obtained. This matter is, however, somewhat beyond our present purpose.

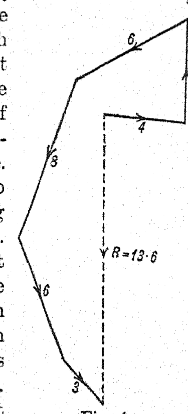


Fig. 4

It is not my intention to give a proof of the "parallelogram" or "polygon" law—the polygon being the most general case, as the triangle is only a particular case of the polygon. This will be found more or less satisfactorily given in books on Theoretical Mechanics. The practical student will probably be content with an experimental illustration of the law. In Fig. 5 is shown an apparatus for illustrating the law of the "polygon of forces." Here six forces act on a small smooth ring, which is allowed to assume a position of rest or equilibrium. The ring is then fastened in position by a drawing-pin, and one of the forces *a* removed. The five remaining forces acting in the five cords are now distinctly out of equilibrium. A polygon is constructed as shown in Fig. 6, and it is found that the side required to *close* the polygon is almost exactly

parallel and proportional (to the same scale as that used for the others) to the force *a* required to produce equilibrium. Or the experiment may be performed by allowing all the forces to remain in equilibrium, and then constructing the polygon, it is found to be very nearly closed. Thus the illustration bears out the law—at least, very nearly. Why do I use the words "almost" and "very

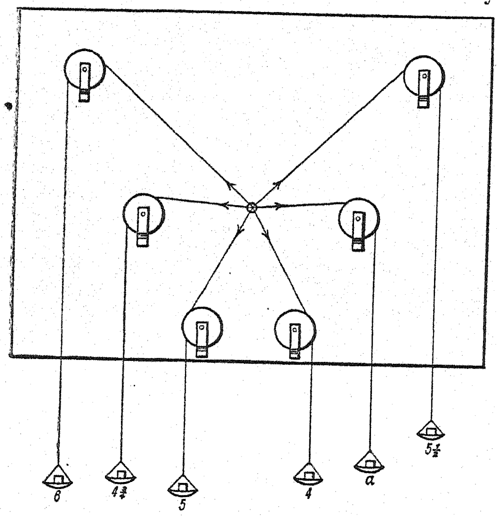


Fig. 5.

nearly" here? Because the apparatus, like all pieces of apparatus, has certain defects, and does *not* exactly represent what we want. In other words, we do *not* know exactly what the forces are which act on the ring, for the force due to the weight at the end of one of the strings is not all transmitted to the ring. There is something about each of the pulleys which to some extent mars our illustration; in other words, each pulley has *friction*,

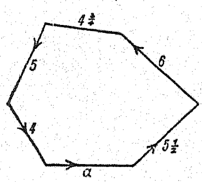


Fig. 6.

which, however useful in its own place, here causes a certain discrepancy to appear in the results. In most of the older books to which reference was made above, many questions and problems are discussed at length in which pulleys *which have no friction* figure conspicuously. Unfortunately, such pulleys are not on sale in London, or anywhere else, and whilst we may try, by making the pivots of hard steel with very fine conical points, and by having the pulleys very light and well made, to *reduce* the ill effect due to friction, we cannot altogether get rid of it. Hence, since we must put up with this ever present, and in many respects curious phenomenon, it is best to investigate some of its effects in cases like that before us.

Mounting a pulley as shown in Fig. 7, and passing a cord round it with equal weights at the ends, there is of course balance. But it is found that there is also balance when one of the forces, or weights, is slightly increased. The *excess* weight required to keep up a steady downward motion of that end of the cord may be taken as representing what we may call the "effect of friction" corresponding to the particular load on the pulley at the time.

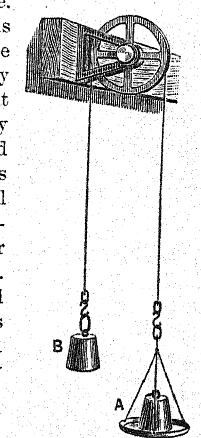


Fig. 7.

When the load is increased it is found that the excess weight has to be increased also, and, in fact, when a few sets of weights are tried, it is at once apparent that the *increase of friction is proportional to increase of load.*

The exact law, however, can only be obtained when the corresponding values of load and effect of friction are plotted as the co-ordinates of points on squared paper; the line joining points thus obtained is very nearly straight, and if the best mean straight line lying among the points is taken, its law will be the law sought.

The method of plotting such results and obtaining the law required will be found discussed in the lessons on Mechanics in the NEW POPULAR EDUCATOR.

Such an experiment as this, simple though it may be, is of value altogether irrespective of the particular matter in hand, for the training in experimental methods which is thus obtained by the beginner is most useful in enabling him to undertake other and more complicated researches. Every reader of these lessons should endeavour to carry out with his own hands many of the experiments to which reference may be made. The pieces of apparatus are mostly of a simple kind, such as the student can construct, and by such experiments a knowledge of the fundamental laws of mechanics is obtained which is of a much more practical nature, and more readily applicable when wanted, than the sort of knowledge obtained by mere reading or listening to lectures. Working out good numerical examples is, perhaps, the next best aid to the acquirement of a practical knowledge of this subject.

RESOLUTION OF FORCES.

In the foregoing we have referred to the *composition* or addition of vector quantities. The

resolution of such quantities is the reverse operation. Thus, in Fig. 8, the force represented by A B is evidently the resultant or sum of the forces represented by A C and A D. The forces A C and A D may therefore be called the *components* of A B, A C being the horizontal and A D the vertical component. Hence, if we are given any force, or other vector quantity, its horizontal and vertical components may be found by projecting the length representing the given force on a horizontal and a vertical line respectively. If the force A B is a units, its horizontal component will be $a \times \frac{AC}{AB}$ units, and the vertical component will be $a \times \frac{AD}{AB}$ units. But the student who has any knowledge of trigonometry will at once see that $\frac{AC}{AB}$ is the cosine of the angle B A C (or α), and $\frac{AD}{AB}$ is the cosine of the angle D A B, or the sine of α.

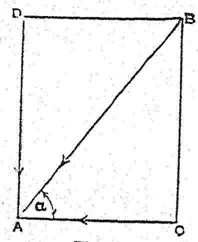


Fig. 8.

Hence, to get the horizontal component of any force, multiply it by the cosine of the angle it makes with the horizontal; or to get the vertical component, multiply by the sine of the same angle. Forces are in equilibrium if the *force polygon for those forces is closed.* Looked at from another point of view, the condition is that the *algebraic sum of the horizontal components of all the forces must be zero*, and also that the *sum of the vertical components of all the forces must be zero.* This gives us at once a method of *calculating* the resultant of a number of forces acting at a point to which we will now briefly refer.

Thus, to find the resultant of the forces shown in Fig. 3 by calculation, we may, for convenience, tabulate our work in the following way, giving to all horizontal components acting from left to right the positive sign; also to all vertical components acting *up*, the positive sign, others being negative:—

Force (Name and Amount).	Acute Angle Force makes with Horizontal ($= \alpha$).	Cos. α	Sin. α	Horizontal Component of Force.	Vertical Component.
O A = 4	0	1	0	+ 4	0
O B = 6	30	·866	·5	− 5·196	− 3
O C = 5	90	0	1	0	+ 5
O D = 3	50	·643	·766	+ 1·929	− 2·298
O E = 8	70	·342	·939	− 2·736	− 7·512
O F = 6	70	·342	·939	+ 2·052	− 5·694
				Sum + ·049	Sum − 13·504

The result is a *downward* vertical component of 13·5 units, and a horizontal component from left to right of ·049 units. The resultant of these two quantities is the resultant required; it would be found by extracting the square root of the sum of their squares. It is evidently very nearly 13·5, and its direction is very nearly vertically downwards. This is evident since we have reduced the given forces to *two* acting at right angles to each other. If we draw, from the given point, a vertical line to represent − 13·504 force-units, *i.e.*, a line equal to 13·504 times the selected unit of length, and drawn from the selected point *downwards*, also from the point a horizontal line representing + ·049 units of force, the diagonal of the rectangle constructed on these lines as sides will represent the resultant of all the given forces in magnitude, direction, and position.

The 47th Proposition of the First Book of Euclid tells us that if a square be constructed on each of the three sides of a right-angled triangle, that constructed on the side opposite the right angle will be equal in area to the sum of the areas of the other two squares described on the sides containing the right angle, and hence the rule given above.

If we place on to the diagonal of this rectangle an arrow-head showing the sense or sign of the force in agreement with the signs of its components, as in Fig. 8, then the four constituents of the resultant force, viz., magnitude, direction, sense, and position, are all represented as the result of our calculation and construction. Some students prefer to trust to calculation alone, hence the following general rule becomes necessary: if θ represent the angle which the resultant makes with the horizontal (positive) position,

$$\text{then tan. } \theta = \text{sum of vertical components} \div \text{sum of horizontal components.}$$

This agrees with the result obtained by the construction shown in Fig. 4, but the method here introduced may commend itself to some students rather than the other, being more accurate if care is taken to use the proper signs. Any convention may be adopted in regard to signs, so long as components acting in opposition have *opposite* signs.

It is not at all necessary that the student who uses this method should understand trigonometry; he may simply regard the sine and cosine of an angle as numbers to be obtained from any book of mathematical tables.

However, the graphic method previously referred to commends itself more readily to the practical man; there is less risk of a *large* mistake being made, and a smaller amount of mathematical knowledge is required, when that method is adopted.

CARPENTRY AND JOINERY.—I.

By B. A. Baxter.

INTRODUCTION.

Technically speaking, a *carpenter* is a worker in timber for building. This definition fairly and shortly gives the meaning that the word conveys, and therefore it will be adopted in these lessons. The word *joiner* may be regarded as indicating a worker who by fitting timbers together produces the neater finishings of buildings. It is, however, so difficult to draw the line between them that we shall regard carpentry as leading to joinery, and afterwards point out the differences and resemblances between the joiner and the cabinet-maker, whose business it is to make the furniture and the movable fittings of our houses.

The carpenter, then, may be said to have his primary business with the carcasses of buildings. Soon after the bricklayer has begun to erect the walls, the carpenter is called upon to prepare sleepers, joists, and wall plates. These timbers are usually of deal, and are, or should be, specified by the architect to be provided to sizes that can readily be obtained. These sizes, which are very various, cover suitable dimensions for nearly all purposes, and can be ascertained of almost any timber merchant or from any builder's price book. The principal widths of these are 7 inch, usually called battens; 9 inch, called deals; and 11 inch, called planks. Thicknesses also vary, and though 3 inches is a very frequent thickness, there are 4-inch deals, while battens are frequently but $2\frac{1}{2}$ inches or even less in thickness.

Sleepers are timbers of oak or deal in the basement of a building supporting the joists, which in turn support the floor boards. The sleepers are arranged parallel to the intended floor boards and at right angles to the joists: they are either supported by piers built at intervals on purpose, or on narrow dwarf walls, on which they are "bedded" with mortar. It is probably from this "bedding" that the curious term is derived; for when in double-framed flooring a similar set of timbers are employed in upper storeys the term "sleeper" is not applied, but the timbers are called "bridging" and "binding" joists.

Joists are timbers used to support and fix a floor. The term is only applied when the timbers are laid horizontally, and for the support of a floor or ceiling. In single floors one set of joists are used for both purposes, the ceiling being usually made of laths and plaster fixed to the lower surface of the joist. In double-framed floors, however, floor joists and ceiling joists are separate timbers.

Wall Plates are horizontal timbers built into the wall in order to fix joists or rafters. Wall plates also contribute largely to the security of the whole building by forming a longitudinal tie and distributing the load over a greater surface. Wall plates are only so called when they rest on the brickwork; in cases where any timbers rest only on their ends in opposite walls, although provided for the support of joists, etc., such timbers are either girders or bressummers.

Girders are main beams of wood or iron which support the floor, and are intended to bind the whole structure together. Girders are often supported at intervals by columns or posts of iron or wood.

Bressummers are also either of wood or iron, and are usually so called when forming part of an external wall or when supporting a wall or partition. Bressummers usually also support the ends of joists, though the name would still be applied to any beam supporting a wall, even if no joists were secured to it. In shop fronts the bressummer is not always at the requisite height to hold the joists of the upper floor. In such cases it is higher, often leaving room below for revolving shutters, giving an appearance of greater height, and by its raised position giving opportunity of so placing the shutters that they do not diminish the height of the shop.

The quality of timber varies very much and depends considerably on the proportion of sap-wood. In the great majority of timber trees this is the outer and immature part, and is the first to decay. The exception to this rule is when the tree is very old and the heart wood has already begun to decay, or where the life of the tree has survived storms or disease.

Very old trees, although apparently sound, are often found to be partially decayed in the middle of the trunk, so that the elasticity and hardness of the wood are replaced by a characteristic brittleness.

As long as a tree is in a healthy condition its top or crown retains its small branches, but when these cease to send forth leaves and break off, it is a sign of decay, and the tree should be cut down and put to some use, for if allowed to stand, its decay, aided by parasitic insects, will proceed rapidly until there remains nothing but a shell composed of the growing zone and a few of the last annual rings, and its value for any purpose will be very much diminished or entirely lost.

A broken-off branch will leave a wound which may furnish an opportunity for fungus spores or boring insects to begin the destruction of the wood.

In deal timber the sap-wood is too obvious to need description. Its bluish colour, and its ready

absorption and retention of moisture, its greater shrinkage, and its inferior appearance, unite in marking it as comparatively of little value. Such wood ought never to be used in any important work or in any exposed situation.

One of the difficulties of wood-working is the liability of timber to shrink. This shrinkage takes place in the width of the wood, scarcely at all in the length, and is greater in the exterior layers of

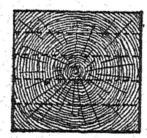


Fig. 1.

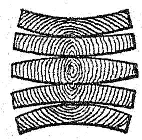


Fig. 2.

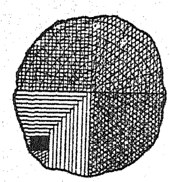


Fig. 3.

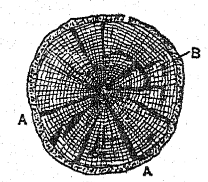


Fig. 4.

wood than near the centre of the tree. When it is remembered that the diameter of the tree remains almost the same while the circumference diminishes, the existence of cracks or, as the workman calls them, "shakes," becomes easily understood. Imagine a wheel the spokes of which remain almost unaltered, while the felloes and tyre become considerably shorter; a breaking must take place, and in the timber this breaking takes the form of "shakes." If, however, the tree is cut into planks while still damp and, therefore, before the shrinking has begun to cause these shakes, then—particularly in thin boards—warping takes place instead of cracking, and as the drying progresses the surface of the board nearest the bark of the tree becomes concave or hollow, while the side nearer to the centre becomes convex (Figs. 1 and 2). To obviate this, timber trees are frequently cut through the centre and again at right angles to the first cut, thereby converting the log into four parts; this is termed cutting "on the quarter." Such a plan gives a greater amount of ornamental appearance of surface, but diminishes the width of the boards (Fig. 3). It is therefore only adopted in cases where the appearance rather than the width of the boards is of importance. The appearance of all wood having well-marked medullary rays is more attractive when those rays are parallel, or nearly parallel to the surface that is seen. Wood, under favourable conditions, will last for long periods of time. The most favourable conditions are dry places and protection from insects and wood-boring grubs; this protection may often be given by paint, varnish, or even linseed-oil on the surface. The most unfavourable places for wood are damp, warm, and dark unventilated situations, especially if decayed organic matter is present, and where the wood is alternately wet and dry, as in piles or posts in tidal rivers. In the first case, various fungi literally feed upon the wood, the conditions being favourable for their growth; and in the second, it has been noticed that decay takes place in the space between high and low water-marks, between wind and water as the common phrase puts it. It ought to be remembered that the durability of wood is not in proportion to its hardness, for all the pines, firs, etc. (conifers), though soft in working, are very durable, no doubt owing to the resinous quality common to them all; while beech, ash, elm, and other harder woods are either (as beech) subject to worm or (like elm) to fungoid growth. The suitability of wood for glued work is a matter for consideration. Of the ordinary woods in common use pitch-pine and rosewood appear to be among the worst. In those woods, therefore, glue must not be implicitly relied on, but will be aided by such forms of construction as will render the structure less dependent on its tenacity. Mahogany, yellow pine, oak, ash, and walnut appear to hold glue well.

There is another consideration concerning wood that ought to be mentioned, viz., twisting or winding. If a piece of wood—say, a telegraph pole exposed to the weather—be examined from time to time, the cracks or shakes which occur through the drying of the outer surface (which was, of course, the sap-wood, and most charged with moisture) will be seen to have a spiral tendency. It is said that a pine tree will, while growing, make a whole revolution between the ground and its lowest branches; if this be so, probably it is caused by the tendency of the tree to follow the sunshine, and as the sunny side is (in northern temperate latitudes) the southern side of the tree, it appears probable that the tree grows upwards and from east to south and west: certainly timber does twist and change its form, so that a flat board of unseasoned wood becomes twisted, or as the workman would say, "in winding." As far as the present writer has observed, some sorts of white deal are more prone to this defect than any other wood in common use.

It may be that this tendency of timber trees to grow towards the light may explain why some tropical wood appears to have alternate portions, behaving in a contradictory manner when the workman's plane is applied to it. If this explanation is incomplete, there is no doubt about the

fact that wood that is cut and planed flat will often twist and become "winding." Nor are some of those expedients sometimes adopted, such as moistening one side, or warming the other, or both, of any permanent value, for at the best such treatment only serves for the time; the only permanent cure for a winding board is, if thin, as a panel, to fix it in a plane; or, if stout, to cut it into smaller pieces, or to reduce it to a flat surface by planing. It may be useful to remind our readers that to cut a winding board into two equal parts reduces the winding to one fourth, while if the board is cut into four equal parts the winding only amounts to one sixteenth of its previous extent.

This is an argument for cutting stuff to required dimensions and seasoning it in small pieces, and a reason why the joiner does not generally prepare his rails in long lengths, afterwards dividing them as required. This seasoning in small pieces is becoming increasingly the custom in the timber trades. The seasoning is more quickly accomplished, shakes are avoided or lessened in extent, warping and winding taking place instead, but are limited by the smaller dimensions of the pieces of wood. All wood thus cut and exposed to the air for seasoning ought to be protected from the direct rays of the sun, and drying at the ends should be retarded by painting, tarring, or glueing the ends of the wood, for it is the rapid drying and, therefore, shrinking of the wood at the porous ends that causes the cracking, or shakes, which too frequently spoils several inches of the ends of the pieces while seasoning (Fig. 4: A, shakes; B, cup shake).

TOOLS.

The typical tool of the carpenter may be said to be the *saw*, and though the timbers—previously referred to as being obtained ready cut to the proper dimensions—are sawn by machinery before the carpenter is called upon to deal with them, yet some sawing must be done by hand. A saw is a tool formed of a plate of steel, the teeth being usually formed by cutting away portions of the edge of the plate, thereby leaving sharp projections which may be restored when blunted by deepening the cut-out portions with a file or otherwise. The projections or teeth act as scrapers, each of which removes a small portion of the material, which remains in the notch or space between the teeth till driven by the movement of the saw to the exterior of the wood. It will be seen, therefore, that the spaces between the teeth ought to be large enough to contain the waste material removed by the scraping action of the tooth. It will be seen that the stroke of the saw ought to be greater than the distance through the wood being cut, otherwise some of the teeth will always be within the thickness of the wood, and as soon as the portion of wood removed by them fills the space between any two teeth, such portions of wood will prevent the teeth from any further action until the saw is removed to liberate the sawdust. From these considerations it will follow that the larger the wood to be cut the longer the stroke must be, and the larger the space between each tooth; and therefore that the saw must be proportioned to the work in hand.

The saw moves in a groove made by itself; it is therefore obvious that the teeth should remove enough material to allow the saw to move without undue friction. To this end all reciprocating saws must have the back reduced or the front increased in thickness. Both these precautions are adopted and the advantage secured: the back is reduced in the manufacture of the saw and the front is practically made thicker by the setting of the teeth. This consists in bending the point of each tooth alternately to the right and left, so that in effect the front or cutting edge is thicker than the back of the saw, and the worker has the convenience of being able to "set" the saw more or less, according to the wood he is engaged in cutting.

Saws that are used with a thrust must be stout enough to resist the bending that would occur to a thinner blade, or else the blade must be put in tension by a frame or otherwise. These remarks are necessary for beginners, but for fuller particulars see "Cutting Tools." Saws used by carpenters must be of suitable dimensions, not exceeding 30 inches in length. Such a saw, termed a rip saw, having about three teeth to the inch, is used to cut along or parallel to the grain of the wood, cutting strips, tenons, etc. A hand saw, which is a trifle smaller, is needed to cut across the fibres: it has smaller teeth, about five or six to the inch. A hand-saw can be used for ripping, especially hard wood; it is also used for cutting shoulders of tenons in large work, and, as its name implies, it is handy for many purposes. A narrow saw will be required for cutting curved lines; these may be had under various names, but that termed a compass saw will be suitable. A large tenon saw will be of service, but smaller saws are chiefly used by joiners and cabinet-makers.

Axes and adzes are used by carpenters to reduce projections, tenons that are too large, and to level rough timber. The adze is a very efficient tool for this purpose, giving good results in competent hands. For the reduction of smaller surfaces than those treated by the axe or adze we have the chisel in several forms suitable for various purposes.

These are called socket, mortise, sash, coach-

maker's, firmer, and paring chisels. Of these the socket chisel is the strongest for general purposes. Mortise chisels (with which may be grouped sash chisels), as the name implies, are used for mortising only. They are made from $\frac{1}{4}$-inch to about $\frac{3}{4}$-inch, and, with sash chisels, which are a lighter variety of mortise chisels, are joiner's tools. The socket chisel, however, is well suited for heavy mortising, and can be had from $\frac{1}{4}$-inch to $1\frac{1}{2}$-inch, or even larger. It derives its name from the steel blade being united with a hollow iron socket, into which the wooden handle is driven.

A mallet of hard wood, usually beech, is needed to drive the chisel used for mortising. This, of course, must be proportioned to the work. A carpenter obtaining a piece of any hard wood may easily furnish himself with a good mallet.

The other chisels mentioned are of various thicknesses in the order named; the paring chisel being the thinnest, and suitable for use with the hand alone. Boring tools of various sorts are used, especially in modern practice, iron bolts and straps being frequently introduced. These tools have been much improved, and both augers for hand use and smaller bits for use with the brace may now be had which combine several excellent features. An auger is a boring tool which is used with a handle, and is in effect a large gimlet. These improved boring tools have (1) a screw point by which the tool is drawn into the wood; (2) one or more chisel-edged circle-cutters which define the boundary of the hole; (3) one or more cutters which remove the core; (4) the stem of the tool has a spiral groove or grooves by which the cut-away material has an easy way of escape. These four features constitute all that is needed to make a good and efficient tool.

A new boring tool has been introduced which is guided by the circumference and not by the centre. By this means it can bore a semicircular recess on the edge of any piece of wood; it is, however, expensive, and too delicate for our present purpose. Hammers to drive spikes, bolts, etc., are too well known to need description. Hammer handles should be oval in section, strong enough to stand the work, and yet not too stout to yield somewhat to the blow; a strong, tough, and elastic wood, such as ash, hickory, or lancewood, is suitable for hammer handles. Squares are the carpenter's model right angle which he uses instead of obtaining the right angle geometrically; this is on the same principle as the draughtsman uses a T-square. Large squares for plotting out the ground and squaring the building walls are often made of wood. Three selected flooring boards are frequently used. A large square of this kind is most easily made by putting Euclid, Prop. xlvii., Bk. I., to practical use. There are three very simple numbers, the squares of two of which equal the square of the third, viz., 3, 4, and 5, the squares of $3 = 9$ and of $4 = 16$, added together, are equal to 25, which is the square of 5. If, therefore, three pieces of wood having holes bored on a centre line and at these proportionate distances are bolted together, a true right angle will be the result, and a useful square easily made. Of course the right-angled corner can be halved, and each of the pieces must be parallel and of equal width throughout.

Bevels for angles other than a right angle must be included in the carpenter's outfit; for large work they can be made of wood, or partly of wood and metal, a finely threaded thumbscrew being very suitable for the centre and to fix the blade. A spirit-level will be required; if the workman fixes the tube himself, as he may have to do in making large levels, he must fix the right side up. These tubes are generally nearly parallel, but slightly curved—the convex side *must* be uppermost, or the bubble may divide and the level be useless. If the block in which the level-tube is placed is 12 inches long, the estimates of error in known lengths can more easily be made. Plumb-rules, lines, and plummet will be required. In this connection an excellent plummet may be mentioned, having a sharp point at the lower part of the weight, the whole being accurately turned. By this means a point can easily be marked exactly vertically below the point of suspension by lowering the weight.

A strong pair of compasses, for scribing and marking arcs, will be required; a good rule, if with scales similar to the working drawings, so much the better; screw-drivers, wrenches, either fixed or adjustable, one or more marking gauges, a mortise gauge, a variety of gimlets and nail punches, a couple of steel-bar chisels—one for prising and one for cutting brickwork.

The sharpening of edge tools, such as chisels and plane-irons, forms a part of the beginner's difficulty. The selection of a suitable stone is the first consideration. Of these Carnarvon is cheap but slow in action, making fine edges, however. Washita is faster and is a favourite stone. Charnley Forest is very fair and moderate in price. Turkey is sometimes very good, but the quality is very variable; it is expensive. Arkansas is excellent for hard, fine steel tools; it is very expensive and slow-cutting, but makes a very fine edge; being very hard, it is durable and especially suited for small tools.

The sharpening of chisels and plane-irons is done by rubbing the tool upon the stone, which is moistened with any thin, non-drying oil; the angle should be about 35° and should be kept as constant as possible—this is a matter of practice—and the

stone kept clean, enough oil being on it to make the sharpening easily done.

When, by rubbing carefully, the worn edge has been removed, the flat surface of the tool must be rubbed, keeping the tool quite flat on the stone, in order to remove the small portion of steel that is bent over by the rubbing of the bevelled edge: this is called removing the "wire edge," and the less there is to be removed the better. See the remarks on this subject in "Cutting Tools."

WOOLLEN AND WORSTED SPINNING.—I.

By Walter S. B. McLaren, M.P.

THE NATURE OF WOOL.

1. To understand the processes of the worsted and woollen trades, and the principles which underlie them, it is necessary to be familiar with the growth and nature of wool. Many writers have discussed the difference between hair and wool without arriving at any satisfactory definition, and it is only by careful microscopic examination that a knowledge of the distinction has been obtained. Chemically they are the same, and wool is merely a variety of hair. There is no absolute dividing line between them, and though a person accustomed to wool would not have much difficulty in saying which of two samples was hair and which was wool, yet the fine hair of some animals so nearly approaches wool, and the coarse wool of some sheep is so like hair, that confusion might easily arise. The two characteristics which distinguish wool from hair are the curl in each fibre and the almost innumerable scales or serratures which cover its surface, and all of which point from the root to the tip, with the points standing out, thus giving it an appearance like the edge of a saw, or a fir cone. Hair, on the other hand, is straight, and though its surface is also covered with similar scales, they are all fastened down so firmly that no points or edges stand out, and thus its surface is perfectly smooth. The chief authority on wool is now Dr. F. H. Bowman, whose work on the structure of the wool fibre exhaustively discusses every branch of the question. "The true distinction," he says, "between wool and hair lies in the nature of the epidermal covering with which the cortical part of the shaft is covered, and in the method of attachment of the scaly plates or flattened cells to the inner layer upon which they rest, and not upon the curly nature of the whole fibre itself, although there can be no doubt but that this waved appearance is one of the chief characteristics of wool. . . . In the wool the cylindrical or cortical part of the fibre is entirely covered with very numerous lorications or scales, the free ends of which have a pointed rather than a rounded form. This enables them when opposed to each other to find their way under the opposing scales, and to penetrate inwards and downwards proportionately to the pressure which is applied to bring them together. In the wool fibre, also, the free margins of the scales are much longer and deeper than in the hair, where the overlapping scales are attached to the under layer up to the very margin of the scale, which can, at its extremity even, only be detached by the use of a suitable reagent. In wool this is quite unnecessary, because the ends of the scales are free to about two-thirds of their length, and are, to a certain extent indeed, turned partially outwards, as can readily be seen by looking at the edges of the wool fibre (when magnified) where the denticulated structure is quite distinct against a dark background."

2. *Growth of Wool.*—The growth of wool is, in its chief features, similar to that of hair. Mr. Youatt, a well-known writer on the subject, thus describes its development and anatomy:—"The skin of the sheep, and of animals generally, is composed of three textures. Externally is the cuticle or scarf-skin, which is thin, tough, and devoid of feeling, and pierced by innumerable holes, through which pass the fibres of wool and the insensible perspiration. Below this is the rete mucosum, a soft structure, its fibres having scarcely more consistency than mucilage, and being with great difficulty separated from the skin beneath. Below this is the true skin, composed of innumerable minute fibres, crossing each other in every direction, highly elastic in order to fit closely to the parts beneath, and to yield to the various motions of the body, and dense and firm in its structure that it may resist external injury. Blood-vessels and nerves, countless in number, pierce it, and appear on its surface in the form of papillæ, or minute eminences, while through thousands of little orifices the exhalent absorbents pour out the superfluous fluid. In the fatty and cellular substance immediately beneath the cutis or true skin—some say embedded in the true skin—there are numerous minute vascular bulbs; they arise from the cellular texture, and penetrate into the true skin; they consist of a double membrane, the outer one of which stops at the pore, or minute aperture in the skin, and between the two membranes a vascular texture has been traced. From the interior and centre of the inner membrane there proceeds a minute eminence or papilla, which, surrounded by the membrane, projects into and through the cutis, while numerous fine filaments

unite to form or to surround a seeming prolongation of the original papilla. In this way it gradually penetrates the cutis, the rete mucosum, from which it takes its colour, and then, either pushing its way through the cuticle—the displaced portion of which falls off in the form of scurf—or carrying a part of the cuticle with it as a kind of sheath, it appears under the form and character of hair."

3. *Formation of the Fibre.*—It must not, however, be supposed that a fibre of wool is a solid structure forced through the skin in the form in which it is afterwards seen. The papilla just mentioned is composed of a great number of very minute cells containing fluid, which is obtained from the blood when that is in a proper condition for supplying it. These cells group together, some in the centre, others round them. As they force their way through the cuticle the fluid evaporates, causing the membrane which forms the cells to collapse; and thus the fibre is created by all the fluid in those cells evaporating, and their walls shrinking in and forming a hollow stalk, which is the cylindrical or corticle part of the fibre, and round which the outer cells are grouped. This cortical part of the fibre is the same both in hair and wool, but it is in the arrangement of the outer cells that the difference consists. They also shrink and form the serratures or saw-like edges which we have mentioned, and of which we shall presently say more. Just as in a saw or a fir-cone each point overlaps the base of the one in front of it, so do the serratures of wool overlap each other. The reason of this is clear. As any given cell comes out from the skin the part in front shrinks first and forms a point. The remainder shrinks in its turn, and is flattened down. The next cell succeeding it is pushed forward, and overlaps its predecessor, forming for itself a point which covers the base of the one before it, precisely in the same way as one point in a fir-cone covers the base of the point in front of it. There is, however, this difference, that wool being gelatinous and of the same nature as horn, the membrane comprising the cells sticks together, and as each soft cell comes out, it forms both a partial covering and bed for its predecessor, and thus all together make one compact and continuous fibre. It must be remembered that as the fibre is composed originally of cells, though dried up and shrunken, the cells always remain, and, under suitable conditions, can revert to some extent to their former nature. Being like horn, they can also be dissolved. It is these two facts which make the operation of washing of so much importance, and underlie the property of felting or matting, which is so characteristic of wool, and which, in brief, may be described as that property which enables a number of fibres, whether woven or merely compressed, to interlock and join together, so that they form one compact whole, and each fibre can no longer be separated, or even distinguished.

4. *Wool, fibrous and porous.*—Wool has a fibrous nature, and can be easily split; indeed, when an animal is in an unsound state of health its hair naturally splits from the point towards the root. It grows from the root, and constantly receives nourishment from the vessels belonging to its bulb. These vessels continue a short way beyond the root, and in the case of a certain disease which affects human hair, known as *plica polonica*, they enlarge even to the extent of allowing blood to pass up the hair, so that each separate hair, when cut, bleeds. This seems to prove that the fibre is a fine tube, although some persons have contended that it is flat and solid. In good health it contains a sort of pulp or oil which gives it softness, and adds to its brilliancy. When clean it is also translucent, and some sorts have a brilliant shining surface, known as lustre. Lustre depends on the nature of the surface of the scales, and to some extent also on their size. It follows therefore naturally that very fine wool is less likely to be lustrous than coarser wool, because on the latter the scales or serratures are larger, and have a larger reflecting surface. But the quality is more important than the size, and in those wools that reflect the light, and so are lustrous, the scales are smooth and polished. This quality may easily be destroyed by washing, either if the water be too hot or the soap too strong. Lack of lustre does not, however, imply any inferiority in the wool, as some of the finest and best wools are without it. It depends on the breed of the sheep, and, in the lustrous varieties, on the way in which the sheep have been fed and attended to.

5. *Serratures of Wool.*—As it is very important that the structure of the fibre should be thoroughly understood, with regard especially to the varying serrations in different classes of wool, and their forms, Mr. Youatt's description is well worth quoting. He says:—"There can be no doubt with regard to the general outline of the woolly fibre. It consists of a central stem or stalk, probably hollow, or at least porous, and possessing a semi-transparency not found in the fibre of hair. From this central stalk there springs, at different distances in different breeds of sheep, a circlet of leaf-shaped projections. In the finer species of wool these circles seemed at first to be composed of one indented or serrated ring; but when the eye was accustomed to them this ring was resolvable into leaves or scales. In the larger kinds the ring

was at once resolvable into these scales or leaves, varying in number, shape and size, and projecting at different angles from the stalk, and in the direction of the leaves of vegetables, *i.e.*, from the root to the point. The extremities of the leaves in the long merino and Saxon wools were evidently pointed with acute indentations or angles between them. They were pointed also in the South Down, but not so much, and the interposed vacuities were less deep and angular. In the Leicester, the leaves are round with a diminutive point or space. Of the actual substance or strength of these leafy or scaly circles nothing can yet be affirmed, but they appear to be capable of different degrees of resistance, or of entanglement with other fibres, in proportion as their form is sharpened and as they project from the stalk; and in proportion, likewise, as these circlets are multiplied. So far as the examination has hitherto proceeded, they are sharper and more numerous in the felting wools than in others, and in proportion as the felting property exists. The conclusion seems to be legitimate, and indeed inevitable, that they are connected with, or, in fact, that they give to the wool the power of felting, and regulate the degree in which that power is possessed.

"If to this is added the curved form which the fibre of the wool naturally assumes, and the well-known fact that these curves differ in the most striking degree in different breeds, according to the fineness of the fibre, and, when multiplying in a given space, increase both the means of entanglement and the difficulty of disengagement, the whole history of felting is unravelled. A cursory glance will discover the proportionate number of curves, and the microscope has now established a connection between the closeness of the curves and the number of serrations. The Saxon wool is remarkable for the close packing of its little curves—the number of serrations are 2,720 to an inch; the South Down has numerous curves, but evidently more distant—the serrations are 2,080. In the Leicester, the wavy curls are far removed from each other, and the serrations are 1,860; and in some of the wools which warm the animals, but were not intended to clothe the human body, the curves are more distant, and the serrations not more than 480. The wool-grower, the stapler, and the manufacturer can scarcely wish for better guides." Dr. Bowman shows that the curves vary with the diameter of the wool as well as with its serrations, and he gives the following table:—

	Curves per inch.	Diameter of fibre.
English merino - - -	24 to 30	$\frac{1}{1562}$ of an inch.
South Down - - - -	13 to 18	$\frac{1}{1272}$,,
South Down - - - -	11 to 16	$\frac{1}{1000}$ of an inch.
Irish - - - - - - -	7 to 11	$\frac{1}{830}$,,
Lincoln - - - - - -	3 to 5	$\frac{1}{650}$,,
Northumberland - - -	2 to 4	$\frac{1}{580}$,,

Authorities have not been able to decide what is the cause of these curves or curls, and Dr. Bowman states that he can assign no mechanical cause for it, although it seems in some way to be occasioned by the unequal contraction of the cells on the two sides of the fibre, first in one direction and then in the other. He comes to the conclusion that, like the peculiar twist in cotton fibre, the curl is inherent in the very nature of wool. But it is remarkable that both the twist in cotton and the curl in wool increase with care in cultivation and breeding, and diminish with the want of it. Indeed, under unfavourable conditions wool deteriorates in every way and tends to revert to hair, which is straight and smooth.

6. *Serratures in Various Wools.*—Anyone can examine these differences for himself. Take some hairs and some fibres of South Down wool and hold them together. The hair will hang straight and smooth; the wool will be curly, something like a corkscrew, and will have a waved appearance. If it is passed between the finger and thumb, beginning with the root end, and drawn out towards the point, it will feel smooth; but if the reverse way, it is sometimes possible to detect a feeling of roughness, as if the fibres were resisting the pressure and passage of the fingers. With a microscope there is no difficulty in seeing the teeth-like edges which thus catch the fingers. They are generally likened to the edge of a saw, but the outside structure of wool is really more similar to that of a long thin fir-cone, rather thicker at the root than at the point, and covered with minute scales which stand out all the way round, and not merely at two flat edges like saw-teeth.

The annexed diagram (Fig. 1), representing various wools, will illustrate this. The first five are each shown twice, as semi-transparent and opaque. In the former state they show the saw-like edges most clearly, but in the latter they appear as they really are, scaly indented fibres, with leaves lapping over each other like a fir-cone. A is a fibre of merino wool, short, fine, and white, and suitable for fine cloth. Its diameter is about $\frac{1}{1200}$ of an inch, and each inch has about 2,400 serrations. E is the finest Saxony wool, a cross between Spanish merino and native Saxon, and is one of the finest in the world. Its diameter is about $\frac{1}{1370}$ of an inch, with 2,720 serrations. The next in fineness is B, the South Down wool, about $\frac{1}{1100}$ of an inch, with some 2,000 serrations. C and D are Leicester

and Lincoln: both stronger, but the latter, which is the longest, heaviest, and brightest of English wools, has comparatively few serrations, and therefore has large scales. F is common wool, G is goat's hair, and H mohair, the brighest of all wools—for it is a wool, though called hair. Cow-hair and human hair, I and J, are also given, the last being of all kinds of hair the softest and most wavy, though very different from the good wools. The coarsest English wool is about $\frac{1}{400}$ of an inch in diameter. The finest of all wools is said to be the American merino, and Dr. Bowman states that he has seen fibres not more than $\frac{1}{3000}$ of an inch in diameter, and with about 6,000 scales to the inch. But such extreme fineness is rare.

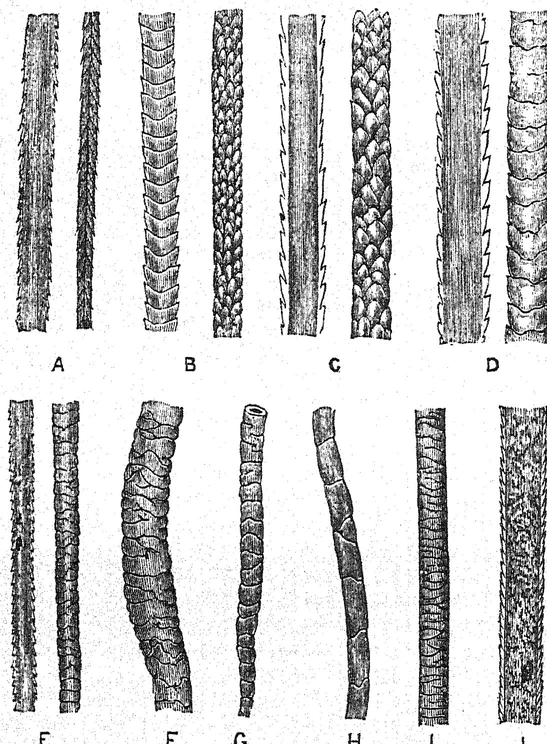


Fig. 1.

7. *Causes affecting Length and Quality.*—The three causes which affect the length and quality of wool are the breed of the sheep, the climate, and the soil. These might be reduced to two, for the breed of the sheep ultimately depends on the climate and the soil; but it is more useful to consider different breeds as quite distinct. The present breeds have been obtained in some instances by careful selections of those sheep which had a tendency to produce such wools as the grower desired and as the climate favoured; until now some sheep will only grow short wool if left in their native district. In other instances, probably the most numerous, nature has decided for herself what length and quality of wool the sheep must produce in each country; no matter what efforts the farmer may make to the contrary, he can only permanently rear short-woolled sheep where nature favours short wool, and long-woolled sheep where she favours length. For instance, South Down sheep grown on the light soil and in the warm climate of the South of England produce short fine wool. If they were taken to the heavy soil and wet climate of Lincolnshire, they would gradually grow long and strong wool, which in time would probably become bright. The Australian sheep were originally imported from England, though they have been crossed with merino sheep. They now grow short fine wool, much finer than anything produced in this country. The farmers there, wishing to increase their weight of wool, cross the breed with Lincoln and Leicester rams. The first year the young sheep give long bright wool, the second year it is much shorter and finer, and each year that the sheep is allowed to live it grows still shorter and finer, till it becomes nearly like the ordinary Australian wool. What is the exact part played by climate and what by soil—which means quantity and quality of food—it is not possible to tell, but it is certain that in the case of sheep more quickly than in the case of any other animal nature provides just such a covering as they need for proper warmth. One writer has said that "sheep carried from a cold to a warm climate soon undergo a very remarkable change in the appearance of their fleece. From being very fine and thick, it becomes thin and coarse, until at length it degenerates into hair." This statement has been endorsed by others, but, as has been shown from the example of Australia, it is by no means correct. It seems, however, approximately correct of East Indian sheep, which grow short strong wool, in some cases like hair, and most of it cross-bred and kempy. It is highly probable, however, that this is due to bad breeding and defective nourishment, and that if merino sheep were taken to India they could be reared with success.

8. *Trueness of Breeding.*—The property for which wool is perhaps most valued is trueness of breeding. In a true-bred sheep each staple of wool, that is,

each lock into which a group of fibres naturally forms itself, will be of equal growth throughout. The fibre will be the same thickness as nearly as possible the whole length, or will be finer at the point than at the root. There will be no shaggy rough wool in it. But if the sheep be cross-bred, or ill kept and exposed to storms, the fibres will be rough at the points, and coarser there than at the roots; the reason of this being that as the wool gets longer, or as it is more exposed to bad weather and hard treatment, nature makes it stronger to resist what it has to encounter, while the part which is next the skin remains fine to give greater warmth. Such wool, even when combed and spun into yarn, never lies as smoothly and evenly as true-bred wool, and is consequently not of as much value.

There is another sort of wool which farmers do not seem to understand, and writers on the subject often ignore, but which is found more or less on all cross-bred sheep, and on sheep which are much exposed and fed in hilly districts. This is known as "kemp," or dead hairs. These kemps vary in length and coarseness according to the breed of sheep. In white Highland sheep they are about two inches long and very thick; in cross-bred Australian they are very short. In the former they cover the under side of the fleece so as almost to hide the wool; in the latter they are so few as not to be of any importance. In some cases half a fibre is true wool and the other half is a kemp, which appears to show that some neglect or disease has caused the sheep to alter the structural character of its wool; though chemically there is no difference. Kemps are, however, all alike in this, that they are a brilliant shining white (except on sheep with grey wool, when they may be black), and they will not dye the same colour as the rest of the wool. They consequently depreciate the value of the wool very greatly, making it only suitable for low-priced goods. They seem to be fibres of wool, possessing no cellular structure, which, owing to the coarseness of the breeding of the sheep, or owing to its exposure to rough weather, have been killed, so far as power to grow long is concerned; but they grow in thickness and hardness till they become solid, glazed, and horny, and thus are unable to receive the substance of the dye. They never alter in the processes of carding, combing, or spinning, nor do they unite with the rest of the wool to form the thread, but lie on the surface, only held down by other fibres of wool which may be wrapped round over them. It should be the object of every breeder of sheep to diminish, if possible, these very kempy varieties of wool.

TECHNICAL EDUCATION:

IN THE UNITED KINGDOM.—I.

By Professor W. Ripper,
Technical School, Sheffield.

Technical Education, a term which only a few years ago was quite unknown, has, from small beginnings, within the space of a few years, become a subject of absorbing interest to educationists, and to all who have the industrial interests of the country at heart.

It had long been felt that the education of the youth of an industrial nation like Great Britain was singularly deficient in that kind of training and instruction which should have special reference to their future industrial needs. The importance of some such provision became more than ever evident at the first great Exhibition of 1851, when it began to be realised how powerful was the competition that might be expected in the future from our Continental neighbours.

Since the time of the great inventors and the industrial revolution which followed the introduction of machinery, enormous changes had been made in the conditions of manufacture. The apprenticeship system had broken down; instead of the master-craftsman with his apprentice living as one of the family, and acquiring his training as a skilled worker under the direct supervision of his master, this domestic system had now given place to the factory. The master was no longer the skilled craftsman, but the capitalist; complicated machinery now did the work which was formerly done by hand—the machine tool was largely displacing hand labour; division of labour was becoming more and more developed every day. The work of the workshop had become a series of specialties, many of which required little skill on the part of the workman, who was in fact a machine attendant rather than a skilled craftsman.

These changes had evidently resulted in the gradual disappearance of the class of highly skilled workers, and the substitution of the machine tool and its attendant, from whom, in many instances, little skill was demanded.

On the other hand, while the introduction of machinery had led to the supplanting of the skilled hand worker, a new demand upon the intelligence and mechanical skill of the country had arisen. It became evident that, in the future, success would depend more upon processes of manufacture, perfection of machinery and mechanical or chemical methods, than upon mere skill of hand, and this involved the necessity for the spread of education, not only of an elementary, but of an advanced character. This condition of things had been realised by Germany and France, but as yet little

or no effort had been made in this country for the promotion of any national system of science instruction.

At the time of the *Exposition Universelle* of 1867 at Paris, a letter was addressed by one of the most distinguished of British jurors to the Chairman of the Schools Inquiry Commission then sitting, in which the following questions were virtually raised:—

Firstly, "Is England really losing her advanced position in those industries which involve the application of scientific knowledge to production?"

Secondly, "Is this retrogression due to her comparative backwardness in the diffusion of applied science?"

Such questions as these are sufficient to show the feeling that prevailed as to the importance of providing in some way for the improved education of the young British workman. It will now be our endeavour to show what has been done in this country to meet the new demands.

Some attempts had been made to introduce scientific instruction by Lord Brougham and other educationists who formed the "Society for the Diffusion of Useful Knowledge" and founded Mechanics' Institutes. These institutions did a noble educational work in their day; but they were only taken advantage of by the few—the better educated sons of the more intelligent workmen, clerks, and others, whose education was sufficient to enable them to profit by attendance at lectures and classes; the condition of our system of national education was by no means such as to enable the sons of the working classes in general to profit by such instruction.

In the year 1835 a Select Committee of the House of Commons was appointed "to inquire into the best means of extending a knowledge of the Arts and of the Principles of Design among the people (especially the manufacturing population) of the country." This committee recommended the establishment of schools of design, and in accordance with their recommendation a committee was formed composed of certain Royal Academicians and others interested in art. These gentlemen constituted the council of the first Government school of design, and the school opened on the 1st of June, 1837, in Somerset House, where certain rooms had been granted for the accommodation of the school.

In 1841 the Government decided to assist in the formation and maintenance of schools of design in the manufacturing districts of the country, and to give annual grants for the training and payment of teachers, the purchase of casts, and the preparation of models for the use of the schools; and in 1852 there were seventeen branch schools in such centres of industry as Manchester, Birmingham, Glasgow, Leeds, and Paisley. An inquiry into these schools showed that they were not working satisfactorily, and in November, 1852, at the opening of Parliament, Her Majesty stated that "The advancement of the Fine Arts and of Practical Science will be readily recognised by you as worthy the attention of a great and enlightened nation. I have directed that a comprehensive scheme shall be laid before you, having in view the promotion of these objects towards which I invite your aid and co-operation." In the following year, 1853, the Science and Art Department was created.

This was the first great scheme of purely scientific training ever started by our own, or any other Government. "It was," as Professor Huxley says, "the creation of a people's scientific university."

It will be evident that, from the beginning, the intention of the Government was to aid instruction in such science and art as should have special bearing upon industry, and the kind of training desired was of a distinctly technical and practical character.

Science Teaching.—It was not until a few years later that a general system of making grants applicable to the whole country was formulated.

Experimental schools were opened at various centres, but after a short time many of them failed, and in 1859 the only places where science classes were in operation under the department were, Aberdeen, Birmingham, Bristol, and Wigan (excluding the navigation schools), and the total attendance at these classes was only 395. In the same year, 1859, the first science minute was passed granting State aid towards instruction in any of the following six subjects:—

1. Practical plane and solid geometry, with mechanical and machine drawing.
2. Mechanical physics.
3. Experimental physics.
4. Chemistry.
5. Geology and mineralogy.
6. Natural history including zoology and botany.

The teachers were required to obtain from the Department by examination a certificate of competency to teach, and payments were made to the teachers on the results of the examination of their pupils. This was the first experiment by the Government in a general system of "payment by results."

The number of new schools and classes rapidly increased, and the progress of the work of science teaching throughout the country may be gathered from the following table:—In

1862— 70 schools,	with	2,543 pupils	in	140 classes.
1872— 948 ,,	,,	36,783	,,	2,803 ,,
1882—1,403 ,,	,,	68,581	,,	4,881 ,,
1891—2,164 ,,	,,	148,408	,,	8,568 ,,

The list of science subjects upon instruction in which aid is given by the department has now been increased to twenty-five.

Scholarships.—Among the important encouragements to the study of practical science should be mentioned the valuable scholarships founded by Sir Joseph Whitworth in 1868 of the total value of £3,000 per year, "for the purpose of promoting the mechanical industry of this country by aiding young men in acquiring proficiency in engineering." These scholarships are administered as follows:—

Thirty exhibitions, each tenable for one year, some being of the value of £100, and the rest of £50 each. Twelve scholarships, tenable for three years, of the value of £125 a year each; four to be awarded each year. The limit of age for candidates is twenty-six years; the competition in theoretical subjects is selected from the list of the Science and Art Department; but the candidate is required to have been engaged in handicraft in the workshop of a mechanical engineer for at least three years.

The effect of these scholarships it would be difficult to over-estimate. The list of Whitworth scholars is a long and honourable one, and it contains the names of men who are to-day occupying foremost positions in our engineering and shipbuilding industries, or doing important educational work.

Further aids and encouragements to the study of science are offered by the Science and Art Department in the shape of Royal Exhibitions of the value of £50 per annum for three years, with free instruction at the Royal College of Science of London or Dublin;

National Scholarships entitling the holder to free instruction for three years at either of the above colleges, with a maintenance allowance of 30s. a week during the session of about forty weeks each year.

Art Teaching.—The art division of the department had for its principal objects, as stated as long ago as 1852:—

(*a*) The promotion of elementary instruction in drawing and modelling.

(*b*) Special instruction in the knowledge and practice of ornamental art.

(*c*) The practical application of such knowledge to the improvement of manufactures.

The history of the art department has been one of continuous growth; the number of students in schools of design before the formation of the department was 6,997, and the magnitude of the work at the present time will be seen from the following table, which shows the numbers receiving instruction in art during the years 1880 and 1890 compared.

	No. of Persons under Instruction.	
	1880.	1890.
Schools of Art	30,239	44,768
Art Classes	26,646	44,065
Elementary Schools	768,661	928,357
Training Colleges	3,568	3,551
Summary	829,114	1,020,741

The Royal School of Mines and Normal School of Science.—These institutions have played an important part in the scientific and technical training of the country, and their origin and history demand some notice. From the "Calendar" of the department we learn that the Government School of Mines was opened in 1851 in response to numerous memorials addressed to the Government by the mining districts of the United Kingdom.

Nine Royal Exhibitions of the value of £50 each, with free instruction, tenable for three years, were given to the school, and many of the exhibitioners became teachers. Though not designed for that purpose, the exhibitions tended to make the school to some extent a training school for science teachers.

The demand for trained teachers did not at that time exist to any extent, and had to be created. The stimulus, however, afforded by the offer of the Department of payment on the results of examination was so effectual that the number of classes rapidly increased, and therefore also the need for more and better instructed teachers.

Short summer courses were commenced lasting about three weeks, and these were taken advantage of, and appreciated by, large numbers of science teachers, who received their travelling expenses to and from London, and a maintenance allowance. Thus a training school for teachers had, through the force of circumstances, come into existence, and in 1881, after complete reorganisation, the school was opened under the title of "The Normal School of Science and Royal School of Mines." This title has since been changed to that of "Royal College of Science, London."

The National Art Training School.—This school is a development of the School of Design originally held in Somerset House, but afterwards removed to South Kensington. As with the Royal College of Science, its special object is the training of teachers or persons intended to fill positions as designers or art workmen. Special facilities are offered in the shape of National Scholarships with

maintenance allowance, to be competed for at the annual examinations of the Department. The course of instruction in the school covers nearly every department of art.

The foregoing brief description of the work of the Science and Art Department is sufficient to show the widespread influence of that department in encouraging the study of science throughout the length and breadth of the country.

By far the greater portion of the students take up the elementary stages of the subject; but provision is made for more advanced work by the arrangement of the syllabus of each subject into Elementary, Advanced, and Honours Stages. The Department has revised the payment of results with a view to the further encouragement of the study of the higher stages, leaving the provision for the encouragement of elementary work to the local authorities.

Notwithstanding the valuable work done by the Science and Art Department, it was becoming increasingly felt that it did not entirely meet the educational needs of those engaged in the skilled industries of the country—in fact, that there was a wide field of practical instruction altogether untouched by it. The work of the Department was confined almost entirely to pure science subjects, and there was very little instruction given having a direct bearing on special industries; and further the hard and fast lines of the syllabus of the Department rendered—and still renders—its adaptation to special needs quite impracticable.

At the various University Colleges throughout the country arrangements existed for providing advanced scientific, and in many cases technical, training; but these courses were not available for the artisan classes.

Efforts had also been made to introduce a more scientific and practical course of instruction in schools of a higher elementary or secondary class. First among such schools were the Allan Glen Institution, Glasgow, the Sheffield Central Board School, and the Manchester Central Board School; at which schools, in addition to a good course of practical science instruction, manual instruction in wood and iron, and machine drawing were also added.

In 1878 a general committee representing certain of the Livery Companies of London was formed to consider in what way the funds of the Companies could be applied for the purpose of assisting technical education. As a result of the report of the committee the City and Guilds of London Institute for the Advancement of Technical Education was constituted, and thus began an organisation whose work and influence on the industrial education of the country are only second in importance to that of the Science and Art Department.

The work which the institute undertook to carry out included:

(1) The building of a central institution intended as a technical university and for the training of technical teachers.

(2) The opening of a technical science college at Finsbury.

(3) The opening of a school of technical art in South London.

(4) The founding of a system of technological examinations, open to students throughout the kingdom with payments to teachers on the results of examinations.

(5) The encouragement of technical instruction in London and in provincial towns by making grants in aid of such instruction.

The full list of subjects of examination embraces almost the whole range of manufactures.

After numerous expressions of opinion by competent authorities as to the importance of definite technical instruction and of the need of Government assistance, in August, 1881, a Royal Commission was appointed "to inquire into the instruction of the industrial classes of certain foreign countries in technical and other subjects, for the purpose of comparison with that of the corresponding classes in this country; and into the influence of such instruction on manufacturing and other industries at home and abroad."

The British Commissioners in summing up their First Report recommended: (1) That instruction in the use of tools should be given in elementary schools. (2) With reference to the apprenticeship schools of France, "we are not sufficiently convinced of the advantages of apprenticeship schools for training ordinary workmen, as compared with the great cost of their establishment and maintenance, to warrant us in recommending their introduction into this country until they have had a more prolonged trial abroad."

Since the issue of that report (in 1882) both these recommendations of the Commissioners have been confirmed by numerous independent educationists and experts.

The Second Report of the Royal Commission was issued in 1884 after visiting educational institutions in every country of Europe and in America; and making exhaustive inquiries as to the efforts made on behalf of technical education, including visits to all the leading industrial centres in Great Britain and Ireland. The conclusions to which the Commissioners arrived are set forth in full in Vols. I. and II. of the Second Report.

At the close of the Second Report, the Com-

missioners sum up with a number of important recommendations, many of which have since that date (1884) been sanctioned by Parliament and adopted more or less throughout the country.

After several unsuccessful attempts to pass an Act in Parliament which would give local authorities the power to aid technical instruction, a Bill was introduced by the Government on July 24th, 1889, to enable a local authority to levy a rate not exceeding 1d. in the £ for the purpose of promoting technical instruction. (TECHNICAL INSTRUCTION ACT, 1889.)

Technical instruction is defined by the Act to mean "instruction in the principles of science and art applicable to industries and in the application of special branches of science and art to specific industries and employments. It shall not include teaching the practice of any trade, or industry, or employment; but, save as aforesaid, shall include instruction in the branches of science and art with respect to which grants are for the time being made by the Department of Science and Art, and any other form of instruction (including modern languages and technical and agricultural subjects) which may, for the time being, be sanctioned by that department by a minute laid before Parliament, and made on the representation of a local authority that such a form of instruction is required by the circumstances of the district."

Manual instruction is defined to mean "instruction in the use of tools, processes of agriculture, and modelling in wood, clay, and other material."

The aim of the Act is clearly to aid the progress of industry by encouraging practical instruction, which, however, is to be *educational* in aim and method, and not for the acquirement merely of wage-earning dexterity.

It is also the intention of the Act to aid the study of branches of science or art or commercial subjects applied to special industries for which no adequate aid is given under the arrangements of the Science and Art Department.

Although the Act was somewhat obscure in some of its provisions, and to a certain extent a compromise, yet there was a general conviction that it might be a useful aid to the spread of technical instruction, providing local authorities could agree as to its adoption and to the distribution of the grant from the rates.

The local authorities in the various industrial centres took steps to consider the question as to the adoption of the Act. The first of the county boroughs to adopt the Act were Sheffield and Manchester, and these were rapidly followed by other boroughs and county councils.

This Act was amended by a further Act—the Technical Instruction (Amendment) Act, 1891—which permitted, among other things, the providing of scholarships, free studentships, etc.

In the year 1890 the efforts hitherto made on behalf of technical education received most powerful and unexpected assistance. A Local Taxation Bill was introduced in Parliament in order to raise a certain revenue from an increase in the duties on beer and spirits; but certain clauses of the Bill having been withdrawn, a large sum of money, previously allocated to the extinction of licences, was now left without any specific object to which it should be devoted. After some discussion in Parliament it was at length decided to place this money, amounting to the large sum of £743,000 in England and Wales, and £50,000 in Scotland, at the disposal of local authorities for the promotion of technical education. The use of the money for the purposes of education was, however, to be optional.

From further statements in Parliament it has been gathered that the permanence of this fund as an annual grant is practically assured, and the result has been an extraordinary awakening on the part of county and borough councils in providing organisations for properly arranging and carrying out suitable schemes of technical instruction to meet the local needs of the various districts.

It will next be our object to describe the nature and extent of the agencies now at work for the promotion of technical education in the United Kingdom.

PLUMBING.—II.

BY A PRACTICAL PLUMBER.

[*Continued from p. 24.*]

JOINTS MADE WITH THE COPPER BIT (*continued*).

Fluxes and Tinning of Copper Bits.—To make solder flow smoothly and easily, certain substances have to be used termed "fluxes," and for different work different kinds are required. Thus, for a wiped joint, a tallow candle is rubbed over the parts; this is termed "touching," and the tallow called "touch"; it does equally well for copper-bit joints in pipes, though resin is also used and is an excellent flux. Plumbers usually keep it in a small canister with a tapering top, with a small nozzle with a hole under $\frac{1}{8}$ inch in diameter. Fig. 16 shows this. I have seen these made with a parting in the centre at D and a lid F at the bottom, this part being used for keeping a little white lead in, which is very handy at times when out on jobbing work. Note there are two kinds of resin; that known as black resin is the best for our

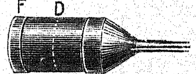


Fig. 16.

purpose. Spirits of salts is another flux that has frequently to be used; it is of no use for lead work, but is the proper thing to use for brass, tin-plate, copper, wrought iron, and zinc. When used for zinc or galvanised iron, it is employed in its natural state as purchased from the chemist; it is then called "raw" spirit, known also as hydrochloric or muriatic acid. It is a virulent poison, and should be kept carefully away from anyone likely to interfere with it; also from bright tools, as it will turn them rusty. For soldering metals other than zinc or galvanised iron, it has to be "killed" and diluted: to "kill" it, pour about a pint into a stoneware jar, and add to it, a few at a time, half a pound of zinc cuttings. This will cause a violent ebullition, by the liberation of hydrogen gas; this will subside, and only a slight fizzing be heard: when this has ceased the spirit is "killed." Take out the spent zinc, and to the liquid remaining add nearly as much water; it is then ready for use. There are several patent preparations for soldering, but none of them have as yet displaced spirits of salts or chloride of zinc, as it is also called.

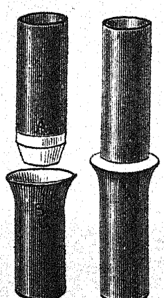
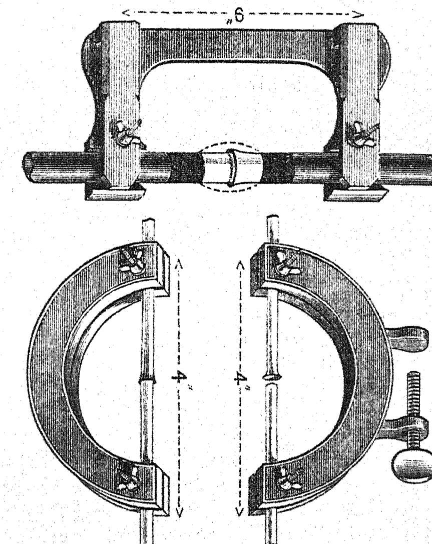


Fig. 17.

To Tin the Copper Bit.—Get it to a cherry-red heat and file (not rasp) the faces of it quite bright, dip it in a pot of the spirits just mentioned, and rub it on a lump of sal-ammoniac with a piece of fine solder, this will give it a nice bright tinned face, and a copper bit should always be in this condition when soldering. I have seen plumbers soldering with just the tip of the bit tinned: it is impossible to do good work with bits in a state like that.

Preparation of Joints.—Take a suitable-sized turnpin and (having previously run the shave-hook or a knife round the inside of the pipe, B, Fig. 17, to take off the rough edge caused by the saw in cutting) with a hammer or mallet strike it so as to open the pipe; take care not to get it one-sided—if you do, it can be corrected by tapping on the opposite side. Having opened it sufficiently, which may be seen by trying in the piece that is to be joined to it, shave round the inside of the piece B, and this piece will be ready; then take the piece A, and with a small rasp bevel off the end as shown. It should also be shaved all round about $\frac{1}{4}$ inch higher than the part bevelled by the rasp; the pieces are now ready for soldering.

Fixing Work in Position.—Sometimes the work is in such a position as not to need any support or fixing, such as when the pipes lie horizontally along joists, etc., or when the lower pipe is fixed and affords some support to the upper one (I am not speaking here of wiped joints), for this purpose the cramps, Figs. 18, 19, 20, are very useful. Their construction and application is easily seen and requires no explanation; they can be made by



Figs. 18, 19, 20.

anyone or purchased very cheaply. Having got the joint ready, the next thing is to solder it: sprinkle a little of the powdered resin round the joint, or rub a little "touch" round, take the copper bit, which should be of such a heat that when cleaned—by wiping with an old piece of carpet, or by rubbing on a piece of sal-ammoniac (*see* "Tinning Copper Bit"), or by dipping in a jar of weak spirits—it will easily and freely melt the solder you are using; hold the strip of solder close to the joint and melt a little on to it, press the point of the iron into it and draw it slowly round, adding more solder if necessary. If you see the solder keep running away, you may be sure that you have got your iron very hot and that your joint is badly fitted. It must also be remembered that a joint is not a good strong one if the metal is simply flowed round the top, the pipes must be warmed to nearly an equal heat with the solder or it will simply stick on and not be properly united, thus it is always best to allow the pipes to get well warmed before the final flow round is made. When the metal is set, and before it gets cold, wipe off the resin—nothing looks worse than a dirty joint; a little "touch" will assist in this.

Horizontal Joints.—Joints in pipes lying in a horizontal position are not suitable for making with

a copper bit, for the reason that they are generally in such a position that it is very difficult to get round them. These, when wiped, are termed underhand joints, and will be treated of later on. But they can be made with a blowpipe, as I will proceed to describe, together with some forms of

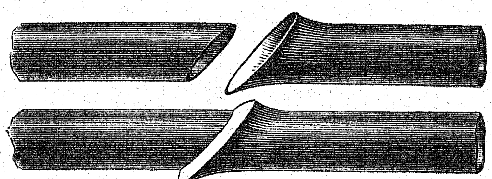


Fig. 21.

blowing-apparatus. Pipes requiring to be joined in this position are better fitted as shown (Fig. 21). As will be easily seen, the solder cannot run away from the joint the same as it could if fitted like the previous example. The blowpipe shown (Fig. 22) is suitable for use in blowing joints in tin pipe, compo.

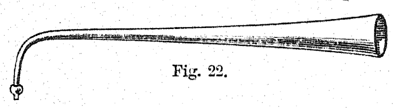


Fig. 22.

pipe, and lead pipe not larger than $\frac{3}{8}$ inch bore. It is used in the following manner: a small bundle of rushes from the tallow-chandler's is held in the one hand—the best way to use these is to lightly fill a piece of brass tube $\frac{7}{8}$ inch diameter and 12 inches long; some wrap brown paper round to hold them, but it is wasteful and untidy as well—a strip of blowpipe solder in the other, and the blowpipe between the teeth. The flame of the rushes is brought within an inch of the joint and the blowpipe brought close to it; a jet of flame is then directed on the joint, the pipe warmed, and the solder run round the joint. A rubbing motion should be given to the stick of solder as it melts—this facilitates its adhering. Some practice is necessary to gain the knack of blowing in this style—the beginner usually finds that it is a difficult matter to keep the blowpipe in the right position to ensure a continuous flame. This difficulty is somewhat lessened by using a form of blow-pipe shown at Fig. 23. In this the blow-pipe is jointed on to a brass case that holds some absorbent material saturated with benzoline or methylated spirit; a sliding tube regulates the flame to the required size. The blow-pipe can, if desired, be detached from the lam · and used in the ordinary way.

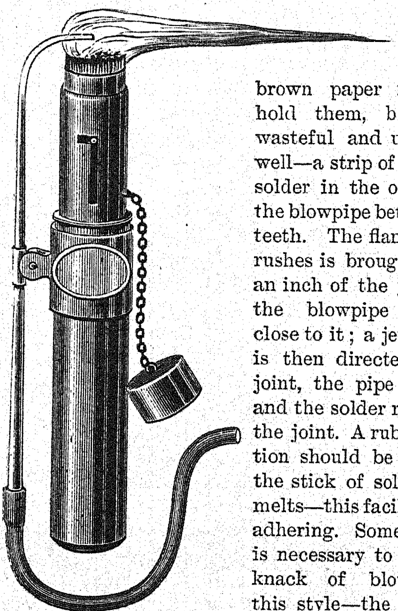


Fig. 23.

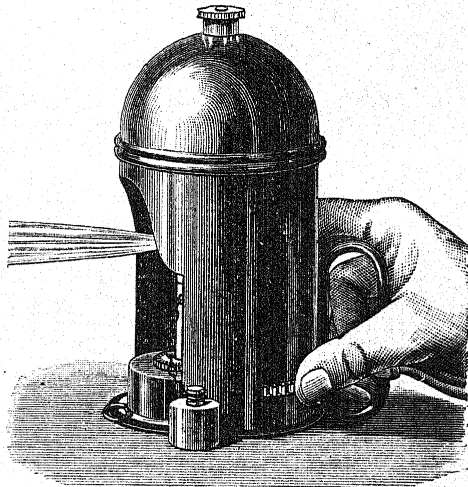


Fig. 24.

For blowing joints in large-sized lead pipes the class of appliances known as blow-lamps or self-acting blow-pipes are very useful.

Figs. 24, 25, 26 illustrate some of the best types of this class. Fig. 24 is the French methylated spirit lamp, improved by a regulating arrangement; by turning the milled wheel A (which can be done whilst using) the flame can be adjusted to any degree. Methylated spirit is used in this lamp. Fig. 25 is also a lamp of French origin—it is known as the Paquelin; it is entirely different in principle from the one just described, and benzoline is used in it instead of methylated spirit. It is a very powerful lamp, and a joint can be made very rapidly in any sized lead pipe from $\frac{3}{4}$ inch upwards; it is not suitable for small pipes, as it is a non-regulating lamp. It is very useful for many things beside joint-making, as it can be used in lieu of irons in soldering leaks in roofs, cisterns, etc. These lamps must be kept clean and the directions accompanying them carried out. The third form (Fig. 26) is somewhat similar in design to Fig. 25, but with wind-guards and flame director; this also burns methylated spirit. There are several other designs

of blowing-lamps, but the principle is the same. Great care should be exercised in using these

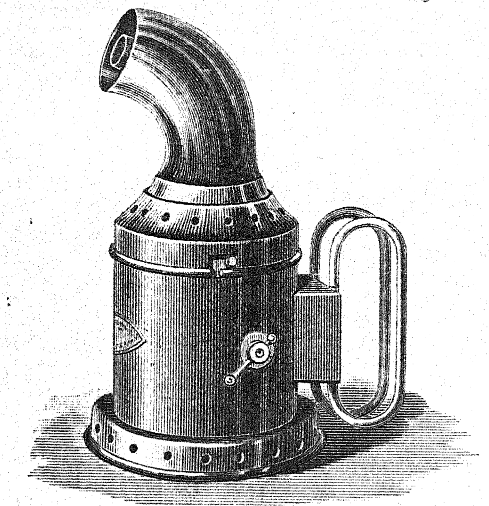


Fig. 25.

lamps indoors on account of the inflammable nature of their fuel.

Connecting Iron or Brass to Metal Pipes.—When any kind of brass or iron fittings, such as a boss or

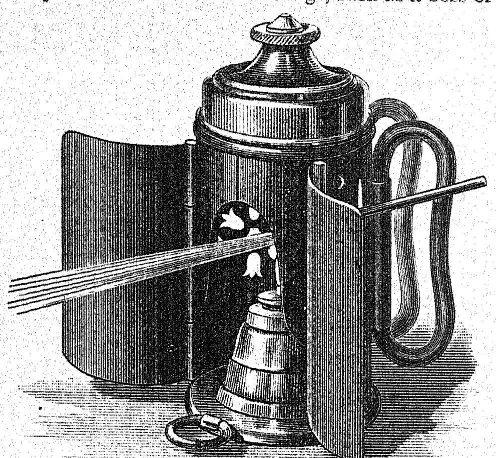


Fig. 26.

ferrule, cap and lining, or union (Figs. 27, 28, 29), has to be connected to metal pipes either by blowing, copper bit, or wiping, it must first be tinned. All plumbers' and gasfitters' brass work that is intended to be soldered is sent out tinned, but to ensure good work they must be re-tinned just previous to using. Some in tinning these fittings use the same flux as they are going to solder them in with, which is a good plan, but undoubtedly spirits of salts is the best, especially for iron; out on a job one has to use that which comes handiest,

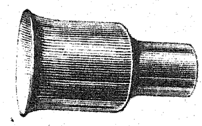


Fig. 27.

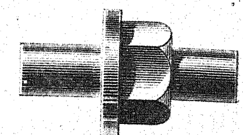


Fig. 28.

which is generally resin. Tin all fittings in workshops if possible; tinning ends of fittings can be done by dipping them in a ladle of solder or with the copper bit, any leather or rubber washers on fittings should be removed, or the heat may spoil them. In soldering bosses into lead pipe a piece of stick is generally used to keep the boss from falling over; though it is often dispensed with, a piece of string tied round under the cap of a union or lining will keep it up whilst soldering.

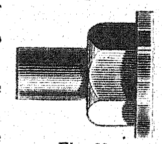
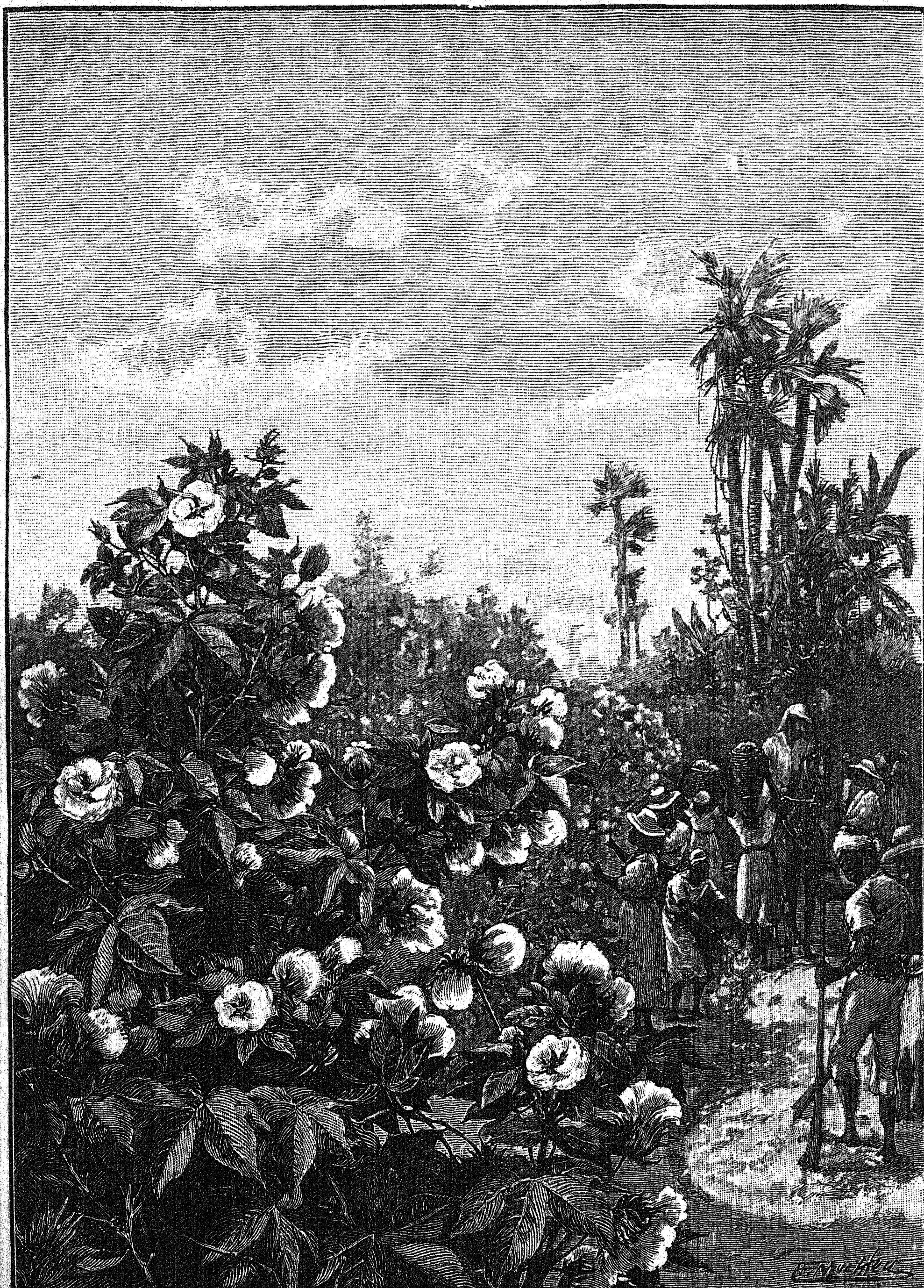


Fig. 29.

Wiped Joints.—We now come to the making of wiped joints. These are more difficult to make than either copper-bit or blown joints, and considerable practice is necessary before skill can be obtained; plenty of plumbers cannot make three joints alike. The preparation of a wiped joint is similar in some respects to that of the joints previously mentioned. When the pipes are ready to be joined, the first thing to do is to rub the ends over with chalk or whiting to take out the grease; the ends must then be "soiled."

Preparation of the Soil.—Soil, or smudge as it is sometimes called, is a mixture of lampblack, chalk, and glue: the lampblack should be calcined—that is, made red-hot in a ladle. Take about $\frac{1}{4}$ lb. of it and mix with a small quantity of chalk ground fine, make into a paste with some stale beer, mix it in the soil pot (which should be of copper and hold about one pint), then add a little glue (about two table-spoonfuls), warm it up, well stir and mix together till it is like thick cream; paint a piece of sheet lead to try it, warm the piece of lead so that the soil dries quickly, and try and rub it off with the hand. Should you find it rub off, add a little glue; if too much glue is present it will peel off, and so it will if the pipe is at all greasy.

Soiling the Pipe.—The pipes should be soiled from 3 to 4 inches past the shaving line, which varies according to the size of pipe. For small pipes, such as $\frac{1}{2}$ inch or $\frac{3}{4}$ inch, $2\frac{1}{2}$ inches is long enough for the joint; that would mean that the shaving would be $1\frac{1}{4}$ or $1\frac{1}{2}$ inch on each piece, but in reality the male end wants a little longer shaving



2 A COTTON FIELD.

by the amount that it enters the female pipe. The soiling must be done true. On large pipes it is a good plan to paste a piece of paper round, this enables a clean sharp edge to be got to the soiling. Straight shaving is also essential to good-looking work; this is secured on large pipe by placing a piece of board at the end and going round with the compasses set to the required length. With regard to small pipes a line should be run round with the shavehook before beginning to shave, and then work to that all round. After soiling and shaving, the joint is "touched," fitted together, and held in place either by the cramps described or by some other means; and let me say that in joint-making there is plenty of scope for ingenuity in rigging up dodges to fix and keep work in position. One way is by means of what are called fixing chisels, which are made of small-sized hexagon or square steel, say $\frac{7}{16}$ or $\frac{1}{2}$ inch, some drawn down to a flat chisel point, and some to a square spike point; these are driven into the brickwork or woodwork as the case may be, and the pipes supported or tied to them to secure them from shifting whilst making the joint. Before describing the making of the joint it is necessary to speak of solder cloths and splash sticks.

Solder Cloths.—The cloths, termed also "wipes," are made of moleskin or stout ticking—some prefer this to moleskin, but I think most plumbers give moleskin the preference. The cloths are of various sizes and thicknesses: for $\frac{1}{2}$ or $\frac{3}{4}$ inch pipe $4 \times 4\frac{1}{2}$ and 4 thicknesses; for 1 inch pipe, $4\frac{1}{2} \times 5$ and 6 thicknesses; for $1\frac{1}{4}$ and $1\frac{1}{2}$ inch, 5×5 and 8 thicknesses; for 2 to 3 inch, 5×6 and 8 thicknesses, and so on. The cloths should be stitched together, and before using some hot tallow should be well rubbed into the side that is to be used, in order to make it work smoothly. When the cloths get very foul, they can be unripped and well washed, and are then as good as ever.

Splash Sticks (Fig. 30).—These are used where the solder cannot be poured on with the ladle. They may be of wood or iron—both have their advantages and defects. If wood is used and the metal is very hot the smoke that arises from the charred wood is very annoying; with iron this defect is done away with, but the soiling is apt to get scratched. If iron is used for a splash stick, it should have a wooden or leather-bound handle, as iron is a good conductor of heat, and you would not be able to hold it after it had been in use a little while. If the ends of wooden ones are scooped out slightly spoon-shaped, they will pick up the metal better.

Fig. 30.

COTTON SPINNING.—II.

By Henry Riddell, M.E.

[*Continued from p. 16.*]

THE COTTON PLANT AND FIBRE (*continued*).

American Cottons.—The great bulk, however, of the cotton grown in the United States is the product of the *Gossypium hirsutum*, which is cultivated over a wide area of the Southern and South-Western States. There are great differences between this variety and the one previously mentioned, in appearance, growth, and in the fibre produced from them. The plant of the Sea Islands cotton grows to a height averaging 7 or 8 feet, but is often found much higher. The blossom is yellow, differing considerably in shape from that of the *Herbaceum*, while the colour is similar; the *Hirsutum* possessing pale yellow flowers. The *Hirsutum* variety is not nearly so high as the Sea Islands plant on an average, reaching 6 or 7 feet as a maximum only. In addition to the marked differences in appearance of the plant and flower, the two American varieties also differ largely in the appearance of the seeds. Those of the Sea Islands are black and smooth, while the *Hirsutum* derives its name from the hairy appearance of its lighter-coloured seeds, which, indeed, are very frequently green-tinted.

The great and essential difference, however, as far as their use to the cotton spinner is concerned, is found in the character of their fibres.

The Sea Islands variety possesses every good quality required by the cotton spinner in a more or less perfect development. The fibre is much finer than that of the other; it is above the average strength; its length is much greater, while the variation in length is smaller; the regularity of its natural twists exceeds that of the other American cottons largely; and the appearance is much better, the fibre being silky, glossy, and well coloured.

The finest yarns can be manufactured from this cotton, and it has been experimentally spun to a length of about 950 miles to the pound. The plant is, however, delicate, and as has been said, deteriorates very rapidly when removed from the coast; it is therefore unable to compete with the *Gossypium hirsutum* in the cotton plantations of the American States generally.

Cultivation.—As has been mentioned, soil has a great influence in determining the nature of the fibre grown in any locality, and it is now found that American cottons from any particular district are not nearly so uniform in quality as they were in the days before the American Civil War. The conditions of cultivation are changed; instead of the large estates, managed with the view

to uniformity and good quality of the product, there sprang up after the war a great number of what must be termed comparatively small plantations, managed each upon its own system. Land which had previously been unoccupied by cotton was pressed into service, and, as a consequence, the variations in the quality of a fibre raised in any neighbourhood have become so numerous that great experience and care are requisite in making a mixing now, compared with the days before the war, in order to maintain the requisite standard of uniformity. As the plant is grown over a very wide area in the United States, of course there are considerable differences in the methods of cultivation, and in the time of sowing and harvesting.

Sowing varies in time from the middle of March to the middle of April. The soils used are very various, the best being a light, rather sandy loam, while the worst is damp clay.

The ground is prepared by ploughing during the winter months, when the manuring also requires to be done, with the view of providing those saline constituents which are necessary to the perfection of the plant. Well drained and irrigated land is required, if a good crop is to be had, as without these advantages it is useless hoping to cultivate cotton with a view to profit. When the season is far enough advanced to lessen to a minimum the risk of night frosts sowing is begun. Of recent years cotton sowing machines have sometimes been used, but the sowing is still most frequently performed by hand in the following way.

The ground having been properly prepared, drills are formed, at a distance of about 6 feet from each other, centre to centre. In these drills the seeds are scattered, and following the sower come a number of young hands with hoes, who lightly cover them with soil.

The width of the space between the rows varies slightly according to the nature of the plant. It is necessary to allow space for free growth and flowering, but the width is settled more in consideration of the room required by the hands in the picking season. After the sowing, and until the young plants have a good growth, it is necessary to carefully keep the fields free from weeds, which would choke the tender shoots, and impoverish the ground so as to greatly injure the crop. The young shoots show themselves in eight to twelve days, and it is during their tender period that night frosts are most to be dreaded, since a single frost will often destroy large areas of the plants, and render it necessary to renew the whole sowing. The weeding requires to be continued, though perhaps the same amount of labour may not be devoted to it, until the time of picking arrives. The plant rapidly develops after the start is made, and in about four months or less is ready to begin picking.

The flower shoots, long slender stems, begin much earlier to show themselves, and the three-shielded case containing the blossom makes its appearance. This, after reaching its full growth, expands rather suddenly, showing the short-lived flower, which in all the American cottons is some shade of yellow, in some cases so light as to be almost white.

In two or three days the flower falls, and in its place appear the small beginnings of the seed pod. This expands to the size of a small walnut, and during its growth the seeds and their adherent filaments also reach maturity, and finally, by their pressure, burst the pod, which usually divides into three or four sections, and exhibits the bunch of fibre. The flowering and fruiting go on together during the rest of the season, and usually until the approaching winter kills the plants.

About the end of July the picking begins, and the cotton fields present a very busy appearance. The field is divided into sections amongst the pickers, and somewhat skilled labour is required in order to pick sufficient cotton to pay a fair wage, and at the same time keep the fibre free from leaf and fragments of the pod, which are so difficult afterwards to remove. About one hundred pounds per day is a fair average for a good picker, and this is thrown into large baskets at the end of each row, and when the day's work is over these are carried to the plantation storehouse, where the cotton remains until it can be ginned.

With alterations suggested by the nature of the climate this description, here applied to the cultivation of American cottons generally, may be used as applying to the operations elsewhere.

The Sea Islands cotton is also grown in other parts of the world to which the seeds have been imported, and good fibre is produced. A few localities may be noticed before passing to the *Hirsutum* variety.

Fiji.—The plant flourishes fairly well in Fiji and Tahiti. The fibre produced is about the same mean length as that of the Sea Islands proper, but has greater variation between the maximum and minimum. The colour is very good, and appearance soft and silky, so that it mixes very well with Sea Islands, although it is considerably weaker than the parent variety. It is clean in cultivation and picking, but very defective in work, owing to the great quantity of undeveloped, matted, or short fibres, causing a large amount of waste in the preparing processes.

Peru.—A class of "Sea Islands" is also grown in Peru along the western coast. It is rather more

valuable than the growth of Tahiti, and about equal to that of Fiji, but very inferior to the parent variety in appearance, either in colour, or in the soft silkiness of the fibre.

Gallini.—The Gallini variety is the descendant of "Sea Islands" seed imported into Egypt, where it is grown along the course of the Nile. It is a very valuable cotton, almost equal to the best growths of Fiji, and but little below Florida in usefulness. The colour of Gallini is against its use for mixing with any other, but different grades of the same are mixed to obtain the yarn required. Its fibres are remarkably fine and strong, but its usefulness is rendered more limited by the quantity of dirt, broken leaf, and badly developed fibre found mixed with it.

The next great class of cottons to be considered is produced by the *Hirsutum*, to which, as has been mentioned, our chief supply of American cotton is due. There are many sub-varieties of this fibre, depending largely upon the district of growth, where there may be something peculiar in the soil, climate, or cultivation to cause a difference in the product.

As far as character of fibre is concerned, the American *Hirsutum* cottons resemble each other strongly, but many things combine to render one variety more valuable than another; a few sorts will be mentioned.

Uplands.—This cotton is grown in parts of Tennessee, Georgia, South Carolina, and Alabama. It is a very useful weft cotton, not very strong, but being elastic and pliable, as well as soft in the fibre, it forms a nice level, round, full thread, such as proves most serviceable in wefts. It is a good mixing cotton, its colour being a light creamy white.

Orleans.—This is the most important of the products of the *G. hirsutum* in America, and is the best of the so-called American cottons. It is largely raised in the plantations along the Mississippi river, and is mostly exported to this country.

There are numerous grades of this cotton, the better classes being very clean and strong in the fibre, as also very uniform in length. The lower varieties are often very inferior in every respect, and require watchfulness on the part of the buyer. It is a very good cotton for mixing, being constantly used with higher-priced varieties to reduce the cost of the yarn. It possesses a nice soft pliable and elastic feel, with considerable strength, rendering it suitable for either warp or weft.

Mobile.—As the Orleans stands at the head of the American cottons in quality, so the Mobile assumes its position at the foot. It is important because of its low price and the quantity to be had, but in quality it leaves almost everything to be desired. It is largely employed for wefts of counts, say, from 10's to 25's, and spins fairly well, but it is very dirty, and sometimes unfairly laden with moisture. The cultivation of this class extends over a portion of Mississippi, Alabama, and Louisiana.

Texas.—As its name denotes, this cotton is a product of Texas, more especially about the Gulf of Mexico.

This cotton at present closely approaches the Orleans in quality if, on the average, it does not equal it. Like the Orleans, there are many grades, the lower qualities being very dirty and laden with sand. The colour is perhaps not so good as that of Orleans, but in general uses it may be classed with that cotton.

Other localities.—Outside of the United States, the *G. hirsutum* is grown in Egypt, where it forms the bulk of the variety known as "White Egyptian," and in Brazil, where it furnishes the variety called "Santos." Neither of these fibres equals the better class of American, the feel being rough and harsh, and the supply far from clean. The fibre, such as it is, has also a part of its value removed by carelessness in the ginning.

The third great class of cotton to be dealt with is the *Herbaceum*, from which the Indian cottons and that known as "Brown Egyptian" are grown. As a whole the cotton produced from this class is the least valuable of the marketable fibres to be met with in our imports. The Indian varieties, however, are important because of their cheapness, rendering possible the making of certain yarns at prices otherwise impossible. The entire class of cotton grown from this species in India is limited in use to the coarser numbers, and it is in such coarse spinnings that the desire for cheapness is most apparent.

Taking the products of the *G. herbaceum* in the order in which they occur in the preceding table, the first to be mentioned is—

Brown Egyptian.—This is by far the most valuable fibre to be described, produced from the species now under consideration. It is native in Egypt, growing about Zagazig and the delta of the Nile, and produces a soft silky fibre which can be spun up to 140's to 150's, although not commonly so used. It is not really brown, but of a beautiful golden colour, and possessed of great toughness and strength, a property which renders it very suitable for warp as well as weft yarns. It is very clean, but like all the finer classes of cotton, and in a greater proportion than most, it holds a quantity of badly developed fibre, causing much waste in the carding and preparation. As in the case of the Gallini, its colour is against its use for mixtures, except in different grades of the same fibre. It spins into

a particularly level round yarn of very good appearance.

Indian Cottons: Hingunghat.—As has been said, the Indian cottons are the most inferior of those to be described, and vary exceedingly in quality. The great extent of territory known as India gives room for a great diversity of soil and climate, such diversity having its natural effect in causing an equally great variation in the quality of the fibre produced. So high is the temperature, and so free is the air from moisture, that over a great part of the country the cotton plant could not be expected to supply a fibre other than harsh and rough, and more or less brittle. Such is the natural effect of heat and want of moisture on any variety of the *Gossypium*, even upon the *Herbaceum*, which is by far the hardiest. Of course where naturally or artificially irrigated, or grown in sheltered and more favoured districts, the plant reaches a greater perfection, thus the highest class of the Indian cottons is produced in the Central Provinces under the name of Hingunghat.

This fibre is strong and dirty; when properly cleaned it spins into a useful series of yarns, say between 20's and 40's. It varies exceedingly in the diameter of the fibres, but this variation it shares with some other sorts.

Dhollerah, Broach, etc.—It is not necessary to describe the remaining cottons of the Indian series further than shown in the table, but the districts of growth require indication.

The *Dhollerah* is raised in the Bombay Presidency, more especially among the Native States.

The *Broach* is also cultivated in the Presidency of Bombay.

Oomrawuttee derives its name from the district of growth, but the Central Provinces and the Berar district contribute to the supply.

Dharwar is another Bombay cotton.

Tinnevelly is cultivated in the more equable and temperate parts of Madras, towards the south.

Comptah.—This fibre is produced in the Central Provinces.

Scinde.—It is to the north-western portion of India we owe our supply of this cotton, from the district bearing the same name.

Bengal—as implied by the title—reaches us from the presidency of that name.

West Madras.—This name is also significant of its origin. The conditions of growth, soil, and climate are not nearly so favourable as in the "Tinnevelly" district, hence the inferiority of the fibre. The cultivation is also inferior.

Peruvian Cottons.—With the exception of the *Smyrna* cotton, which also belongs to the *Herbaceum* variety, and is grown in Asia Minor, in the Turkish territory, and also in the Greek islands, the remaining varieties in the table belong to the *G. peruvianum*, which is esteemed by most authorities to be a sub-species of the *Barbadense.*

They are about equal on an average in value to the best classes of the American cottons produced from the *G. hirsutum*. In order of appearance upon the table they are as follows:—

Rough Peruvian.—This cotton is a variety of the *Peruvianum* indigenous to Peru and Brazil. It is a fibre of fine soft appearance but harsh in the fingers, remarkably clean, and free from broken leaf.

As it spins up to about 70's, it is a really useful cotton, and by reason of its clean state brings a very good price in the import trade. Strangely enough the Peruvian plant is perennial, bearing crops several years in succession, and differing in this respect from any of the other varieties here described. In its first season the plant spends its energies in growth, while after three or four years old age tells upon it, and the fibre loses its manufacturing properties and only wastes the ground.

The colour is light cream, and this cotton mixes well with other Brazilian cottons.

Smooth Peruvian.—As indicated by the name this variety of the *Peruvianum* differs in appearance and in feel from the preceding. The fibre is soft, and very regular in diameter, but unfortunately carries a considerable quantity of the undeveloped filaments, which greatly lessen its value. It is a good mixing cotton, suiting well with the *Orleans*, and enabling a greater range of production to be obtained from the latter. It is better fitted for wefts up to 60's or 70's than for warps.

West Indian.—This cotton is produced in several of the West Indian islands, including Jamaica and Cuba.

It largely resembles the *Rough Peruvian* in appearance, but is very far from being so clean, or so carefully cultivated. The fibres are not very uniform in diameter, but possess a singular uniformity in twist, which extends perfectly regularly from base to tip of the fibre. It is comparatively a weak cotton.

Pernambuco.—This is the finest of the Brazilian cottons, and the longest in the staple. It resembles the *White Egyptian* in appearance, and is used frequently in mixture with it. The feel is comparatively rough and wiry, and alone it is most suitable for twist yarns.

Ceara and *Maranhams.*—These two cottons, which are grown in the north-east of Brazil and along the coast, resemble each other in character, but differ in colour, which however is by no means a fixed quality in Brazilian cottons. In essential

detail they resemble Pernambuco, and like it may be mixed with either Egyptian or American.

This completes the review of the tabulated cottons, but of varieties not represented on the table two may be mentioned, they are the African and Australian cottons.

The *African* is the product of the indigenous *Herbaceum*, and is grown about Liberia, Natal, and the west coast. It is a fairly strong and very clean fibre, but consequent upon the great heat and absence of moisture, the amount of short half-matured fibre is very great, causing it to be a wasteful cotton in the working.

Australian.—While a very large portion of the Australian continent is suitable for cotton cultivation, there are great difficulties in the way, in the labour question among others.

The fibres of the small quantity of cotton produced in this continent are comparatively long and weak, and of rather a poor spinning quality.

With this variety is concluded the division of the lessons concerned with the character and cultivation of the cotton, the next section beginning the consideration of the manufacturing operations, including, for several reasons, the ginning and baling of the cotton received from the fields.

STEEL AND IRON.—II.

By William Henry Greenwood,
F.C.S., M.Inst.C.E., M.I.M.E., Assoc. Royal School of Mines.

[*Continued from p. 8.*]

IRON AND STEEL (*continued*).

Ferrous Silicates.—Pure silica and oxide of iron unite at a white heat to the production of a fusible ferrous silicate, and thus, during the ordinary operation of welding together two pieces of iron, the blacksmith removes any oxide or scale which, during the process of heating the iron in the smith's fire, forms upon the surfaces of the bars to be welded, by throwing upon the heated surfaces a quantity of siliceous sand, whereby a readily-fusible ferrous silicate is produced, which flows away under the pressure of the hammer or press employed in welding together the two surfaces of the metal, and so leaves the surfaces to be united quite clean and in the best condition for being successfully united. Ferrous silicates of variable composition are formed as the result of the union of oxygen with silicon and iron; hence the various slags and cinders produced in the blast furnace, the puddling, refining, re-heating, or other furnaces employed either in the production or subsequent manipulation of iron are essentially ferrous silicates. The silicate (Fe_2SiO_4) yields about 70 per cent. of ferrous oxide and 30 per cent. of silica; it melts at a white heat, but if heated with access of air it suffers partial decomposition, with the production of ferric oxide and the separation of silica. In this manner when the slags of either the puddling or re-heating furnace are roasted with access of air during several days in suitable kilns or ovens, a highly refractory dark grey and lustrous body is obtained, which consists essentially of ferric or magnetic oxide, with small proportions only of silica. This roasted cinder is known as "*bull-dog*," and is used largely for making the bottom of puddling furnaces. During the roasting of tap- or forge-cinder from the puddling furnace for the production of bull-dog, there liquates from the mass two other products: the one which collects in the bottom of the kiln is known as "bull-dog slag"—it is more silicecus than "bull-dog," and carries with it much of the phosphorus contained in the cinder; whilst the other product is still more siliceous and phosphoric, is also more fusible, and runs away from suitable openings left in the kiln. When ferrous silicate of the composition Fe_2SiO_4 is strongly heated with carbon, about two-thirds of its iron is reduced, leaving behind a more siliceous slag having a composition represented by the formula $Fe_2Si_3O_8$.

Alloys of Iron.—Pure iron unites readily with many other metals, yielding alloys, which in most instances are, however, without commercial importance. It is only the alloys of metals with cast-iron, malleable iron, and steel that need be considered in these pages, and these will be referred to when considering cast-iron, etc.

Pig- or Cast-Iron.—As previously stated, iron is met with in commerce either as malleable iron, as cast-iron, or as steel and ingot iron. Now malleable or wrought iron, owing to the *simplicity* and *ease* of the methods by which it can be obtained *direct* from the iron-ores, might claim first attention; but since by far the greatest proportion of the wrought-iron of commerce is made from pig-iron and therefore *indirectly* from the ore, it will be more convenient to consider pig-iron first. Also before considering the constitution and modes of occurrence of iron-ores, and of their treatment for the production of pig-iron, it may be well to examine the more prominent physical, mechanical, and chemical qualities of pig-iron, and its qualities are affected by the presence of small quantities of various other metallic and non-metallic elements.

Pig-Iron—of which about $7\frac{1}{4}$ million tons was produced in Great Britain during 1891—is the granular crystalline combination of iron with carbon, silicon, sulphur, phosphorus, and manganese, and smaller proportions of other metals, such as arsenic, titanium, copper, chromium, etc.,

which is produced when certain iron ores are treated in the blast-furnace under suitable conditions.

Pig-iron consists essentially of iron with from 2 to 4·75 per cent. of carbon, of which the latter exists partly in a *state of solution* or *chemical combination* with the iron, and partly as mechanically-distributed *uncombined* or *graphitic* carbon. All pig-iron contains carbon in these two forms, but the ratios of the combined to the uncombined carbon vary in different varieties of pig-iron, from the greyest iron where the carbon is almost wholly in the *uncombined* form, to the hardest white iron in which only a small proportion of the carbon exists in the graphitic or uncombined state.

Upon the relative proportions of the two forms of carbon, modified by the presence in varying proportions of the foreign elements before-mentioned, depend the wide variations in the colour, hardness, strength, fusibility, specific gravity, behaviour when treated with acids, and adaptability of the metal to the special purposes to be subsequently referred to; but all varieties of cast-iron are characterised by the almost total *absence of ductility*, they are also *unforgeable*, and will not weld; it is also more brittle, less tough, and is usually harder than malleable iron.

Pig-iron is usually found in commerce in the form of oblong blocks or pigs of ◠ section, and about three feet in length, the metal being run for this purpose direct from the blast-furnace into open grooves, or channels of the above section, formed for that purpose in the damp sand of the *pig-bed* in front of the tap-hole of the furnace. Such pigs, when broken by the hammer, or by dropping them across a △ shaped block, present, if grey iron be the subject of operation, a dark grey, granular, crystalline or scaly fracture, with a strong metallic lustre; whilst the colour will be of a lighter grey, less lustrous, and the metal harder and more brittle, as the proportion of combined or dissolved carbon increases, and the uncombined or graphitic carbon becomes less. In the greyest iron, scales of graphite in very thin plates can be seen distributed over the faces of the crystals of the metal, and by careful treatment the scales of graphite can be detached and collected. The graphite is also more or less separable by sifting and levigating the very fine borings of grey pig-iron. White iron, again, contains the largest proportion of combined or dissolved carbon, with smaller proportions only existing in the uncombined or graphitic state; such iron is harder, whiter, coarsely granular, and more flaky in appearance than grey iron.

The separation of flakes of graphitic matter, or *kish*, during the slow cooling of molten grey iron, has been referred to (p. 8); but if the same metal be cooled suddenly, as by running it into cold metal moulds, then no separation of the graphite occurs, and a hard white metal is produced; hence *fluid* and also *chilled* cast-iron appear to be capable of holding a larger amount of carbon in solution than the same metal when cooled more slowly from a state of fusion. Thus it is inferred that *molten pig-iron may be a solution of various solid and gaseous substances in liquid iron*, and that the form they assume in the solidified metal depends upon the method and rate of cooling, both before and after solidification. The scum or kish already described is also often notably richer in sulphur and manganese than the pig-iron itself.

Grey pig-iron, owing to the higher temperature employed in its production, often contains larger proportions of foreign substances, like silicon, aluminium, magnesium, etc., than does white iron smelted from similar mixtures of ores, etc.

In the process of chill casting, where the fluid metal is poured into metallic moulds, and the heat is thus rapidly withdrawn from the surface, the outer crust is thereby converted into hard white iron, whilst the body of the castings usually retain the soft character of grey iron. The depth and degree of the chilling are generally deeper according as the pig is low in silicon and as the thickness of the mould increases. From this cause the flat plates or pigs of Swedish pig-iron often present on fracture a white skin with a grey interior, the result of the Swedish practice of running the pig-metal into open cast-iron moulds.

The *mottled varieties* of pig-iron stand intermediate between the two extremes of grey and white iron, and exhibit a decidedly veined or mottled fracture, as though the white iron was distributed in small detached portions, or in veins, throughout a matrix of grey iron; and according as the proportion of white iron is greater or less, the pig-iron is described as *strongly* or *weakly mottled*. Grey iron is more fluid when melted than white iron, but it requires a much higher temperature for its fusion; thus, whilst grey iron only melts at a temperature of about 1,600° C. or 1,700° C. (2,912° Fahr. to 3,452° Fahr.), white iron melts at a temperature of from 1,400° C. to 1,500° C. (2,532° Fahr. to 2,732° Fahr.). White iron contracts in passing from the liquid to the solid state, and it passes through a soft pasty condition before complete fusion occurs, as also through a similar condition in assuming the solid state after fusion. Grey iron, on the other hand, during melting passes directly from the solid to the fluid state, and *vice versâ*, and it also expands at the moment of its

solidification from the fluid state, thereby insinuating itself into the finest lines of the moulds in which it is contained, whilst white iron, as just stated, contracts under these circumstances. Hence grey pig-iron is in request for foundry purposes, and more especially for the production of light ornamental and intricate castings, so that it has become usual to call the softer grey grades of pig-iron *foundry pig*, in contradistinction to the harder and whiter varieties, which are described as *forge qualities*.

Cast-iron in its fused state *occludes* or holds in solution gases like hydrogen, which gases are to a certain extent liberated as the metal solidifies, giving rise to the honeycombed or unsound structure so frequently observed in cast-iron castings.

Cast-iron expands in length by heating and then cooling either suddenly in water or by gradual cooling in the air. Pig- or cast-iron suffers decomposition when exposed to the action of sea-water, or more rapidly when exposed to the joint action of sea-water and of the atmosphere; by such prolonged exposure the metal becomes a soft porous mass having the form of the original specimen. When atmospheric air (as in the Bessemer process for the conversion of pig-iron into steel) is blown or forced through molten grey pig-iron, the metal becomes intensely hot, whilst its carbon, silicon, and manganese are largely oxidised and removed in the manner to be more fully described when speaking of the Bessemer process for the manufacture of steel.

The specific gravity of pig-iron varies from 7·1 in grey to 7·5 in white iron; and cold solid cast-iron floats upon the surface of the molten metal, not, however, because of any greater density of the fluid over the solid metal, but because of the sudden expansion of the cold solid metal from contact with the much larger body of molten iron into which it is introduced, and whereby the density of the solid metal is reduced; for it is noticeable that the larger pieces of cast-iron, on introduction into the fluid metal, first sink and then rise again to the surface of the molten metal.

The strength of cast-iron varies according to its chemical composition, the mode of its production, and the treatment it has received after leaving the blast furnace. Cold-blast iron is stronger than hot-blast from the same ores, although except that the silicon will be a little higher in the hot-blast iron there is but little difference chemically between the two; and hence the superiority of cold-blast iron is probably largely due to its molecular structure. For like reasons, in America, cold-blast charcoal iron is preferred for chilled iron wheels, since such iron takes a deeper chill and wears better than hot-blast iron from the same ores. Annealing diminishes the strength of cast-iron; the presence of silicon likewise impairs its tensile strength, whilst sulphur in small quantities increases the strength; but phosphorus, again, if present in any considerable amount, decidedly weakens cast-iron. The strongest pig-irons, then, are such as have been smelted with cold-blast from either hæmatites containing but small proportions of silica, or from argillaceous ores.

Remelting for a certain number of times improves the strength of cast-iron, since the earlier remeltings each eliminate a certain amount of silicon, which is oxidised and passed into the slag; also whilst the total amount of carbon remains practically the same, a proportion of the graphitic carbon is changed at each fusion into combined or dissolved carbon, so that the iron approaches after each remelting nearer to the character of white iron, which, although stronger than grey iron, is less tough, and hence repeated remelting renders the iron less applicable for the production of castings where toughness is required, as for structural ironwork.

The *tensile strength* of pig-iron varies between 4 and 14 tons to the square inch of section, but the average for good cast-iron is about 8 tons. The *transverse* and *torsional strength* of pig-iron is low, each varying between 1·5 and 4·5 ton per square inch; and it has an average *shearing strength* of 12 tons to the square inch; whilst its *crushing strength* ranges from 25 to 60 tons, the average of good sound specimens being from 40 to 45 tons per square inch of section; but these figures vary with the length of the test-piece employed, the higher figures for the crushing strength being obtained with short test-pieces. Owing to the high strength of cast-iron under a crushing or compressive stress, this metal is usually employed in the constructive arts for columns, struts, etc., and but rarely in such members of a structure as are subject to torsional, tensional, or transverse stresses. Cast-iron is thus stronger than wrought-iron in compression, but much weaker in tension; and within a limited range of stress it is tougher, or permits of a greater degree of deformation than wrought-iron, but its range of deformation is not large—hence it is not so safe as wrought-iron when subject to suddenly applied stresses.

Engineers generally require the cast-iron used for structural purposes to be grey, and such that a cast bar two inches deep and one inch in thickness, supported on centres 3 feet apart, will not break under a load of less than 28 cwt. supported at the centre. In pig-iron a uniform dark-grey colour, with strong metallic lustre, indicates toughness;

whilst a dark colour, an absence of metallic lustre, with a dull more or less leaden hue, and a slightly mottled appearance, indicates a weak iron; but if the iron be light grey in colour, with a high lustre, then it will be strong and tenacious; whilst a light grey colour, without lustre, shows an iron which is hard and brittle, the brittleness being more strongly marked as the iron becomes of a dull white or greyish-white colour. The pig-iron smelted entirely from ores (mine) without any admixture of puddling-cinder or slag, is known as "*all-mine pig-iron*," whilst where slag or cinder is added to the furnace charge, the product is known as an inferior pig-iron, "*cinder-pig*." *Glazed* or *blazed* pig is also an inferior, highly siliceous pig, often produced when a furnace is first started. *Spiegeleisen* is a hard white highly manganiferous pig-iron, while a pig-iron still richer in manganese than the last mentioned is called *ferromanganese*. The pig-irons smelted from hæmatite iron ores—and which owing to their comparative freedom from sulphur and phosphorus are well adapted for conversion into steel by the Bessemer or open-hearth processes in acid-lined vessels or furnaces—are described as "*Hæmatite*" or "*Bessemer pig-irons*"; and another class of pig, low in silicon but rich in phosphorus, which is specially manufactured for conversion into steel by the Basic process, is sometimes called "*Basic pigs*." Further, the pig-iron is described as "*hot*" or "*cold blast pig-iron*," according as hot or cold air is employed in the blast-furnace; and lastly, there is a very limited production of pig-iron in which charcoal is the fuel employed, and such metal is spoken of as "*charcoal pig*." Besides these classifications each pig of iron is marked with a name, letter, or brand indicating the place of its manufacture, and lastly, it is usual to distinguish the various qualities or grades of every brand by numbers or marks which serve to indicate to the forge or foundry manager the purpose to which the pig-iron is applicable. Thus in the Cleveland district, according to the colour, strength, and general appearance of the fracture of a freshly broken pig, the metal is described as being of No. 1, No. 2, No. 3, No. 4, or No. 4 forge quality; whilst in the Lancashire district the numbering is the same except that the No. 4 forge, or strong forge of the Cleveland district, is represented by V. Hæmatite pig-irons are again described as No. 1, No. 2, or No. 3 Hæmatite or Bessemer pig-iron. Of the Lancashire or Cleveland numbers, No. 1, No. 2, and No. 3 are especially applicable to foundry purposes and for special castings; No. 4 is also available for foundry purposes if mixed with other softer irons; whilst No. 4 forge or V is used for conversion into malleable iron in the puddling furnace, and cannot be advantageously used for foundry purposes. The market value of the several grades usually decreases from No. 1 to No. 4, the higher number being the cheaper iron.

No. 1 pig-iron of any brand is the darkest grey, the most graphitic, the softest, most fusible and least tenacious of the numbers. The pigs break with a dull leaden sound with a largely granular fracture; but it makes the most accurate castings, and is thus used for light ornamental castings not requiring great strength. Besides being the richest in graphite, it is usually also richer in silicon and manganese than the higher numbers. No. 2 pig-iron is lighter in colour; usually the surface of the pig is smoother, finer in grain, more regular in fracture, also a little harder and stronger than No. 1, but is not quite so fluid when in the molten state. No. 3 is still lighter in colour, its crystals are much smaller, the fracture smoother, more compact and dense-looking; it is also much harder, stronger, and tougher than the lower numbers, and is consequently largely used in conjunction with scrap for the large castings required in structural ironwork. No. 4 is stronger than the lower numbers, it is also whiter in colour, more lustrous, with a granular, uneven, and more or less mottled fracture. No. 4 forge, strong forge, or V, is almost white in colour, presents a dull flaky appearance on fracture, and is unfit for foundry use owing to its want of fluidity when melted: it is used entirely for conversion into malleable iron by the puddling process.

ANALYSES OF CAST OR PIG-IRON.

	Cleveland Hot-blast Foundry Iron.		Cleveland Mottled Iron.	Cleveland White Iron.	No. 2 Hæmatite Pig.	Staffordshire Cold-blast No. 2.	Swedish Spiegeleisen.	French Ferromanganese.	Middlesbro' Glazed Pig.
	No. 1.	No. 3.							
Graphitic Carbon	3·20	3·00	1·50	0·10	2·57	2·68	3·80	6·00	2·59
Combined or Dissolved Carbon.	0·20	0·35	1·50	2·90	1 17	0·45			0·79
Silicon	3·30	2·80	1·70	1·30	1·75	1·72	0·25	trace	5·13
Sulphur	0·01	0 04	0 35	0·45	0 01	0·04	0·01	trace	0·17
Phosphorus	1·50	1·46	1·52	1·53	0·04	0·68	0·03	0·175	1·12
Manganese	0·75	0·52	0·35	0·30	0·130	0·54	20·35	46·60	0·77
Iron	91·04	91·83	93·08	93·41	94·30	93·89	75·10	47·22	88·89

PROJECTION.—II.

[*Continued from p.* 12.]

PROJECTION OF SOLIDS (*continued*).

ALL the solids above mentioned are developable —*i.e.*, their boundary surfaces can be formed from a flat sheet by cutting to shape, and folding without any extension or compression at any point of the sheet. The development of some of the principal solids is shown (Figs. 10 to 20) by the

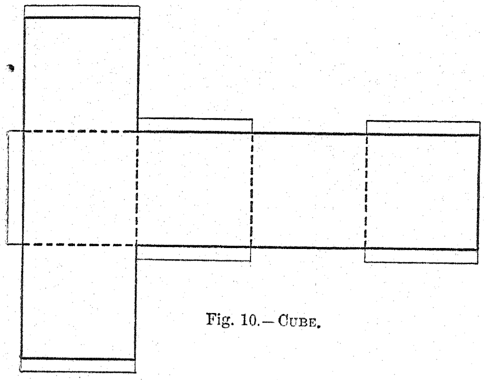


Fig. 10.—CUBE.

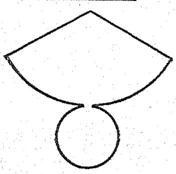


Fig. 17.—CONE.

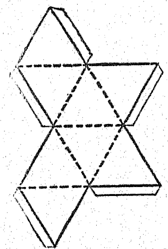


Fig. 18.—OCTAHEDRON.

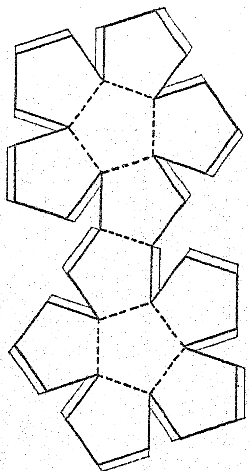


Fig. 19.—DODECAHEDRON.

thick full lines. The thick dotted lines show where the paper must be folded. The narrow strips indicated by the thin lines are for the purpose of retaining the edges in position. They may be gummed down, if a permanent model is required, but if the cardboard or stout drawing-paper be cut, as shown in Figs. 10 to 20, it will be found that the narrow strips on being folded over keep the model in position without the use of gum. Thus the student may have a set of collapsible models of the solids he is studying. It is essential that the student make himself a set of these models. These developments should be drawn with rather a hard pencil, which should be pressed hard on the paper so as to slightly indent it, and it will be found that the paper can be folded exactly at the lines

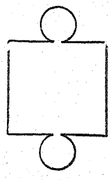


Fig. 11. CYLINDER.

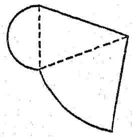


Fig. 12. – HALF-CONE.

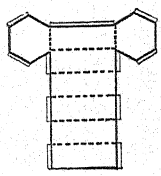


Fig. 13. HEXAGONAL PRISM.

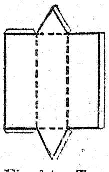


Fig. 14.—TRIANGULAR PRISM.

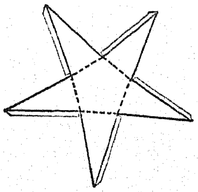


Fig. 15.—PENTAGONAL PYRAMID.

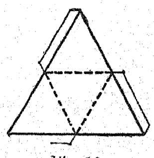


Fig. 16. TETRAHEDRON.

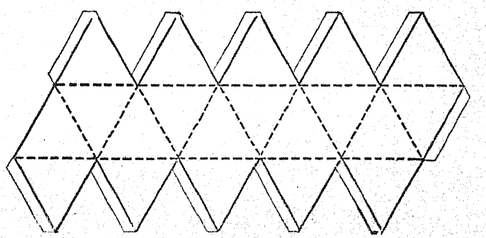


Fig. 20.—ICOSAHEDRON.

required. The paper should be folded so that the pencil lines are on the outside of the model. In Figs. 15, 16, 18 and 20, the narrow strips may be enlarged to the shape of a triangular face; the resulting model will be neater.

Problem.—To draw plan and elevation of a solid in its simplest position. We will show later on, that if we have a plan and elevation of a solid in any simple position, we can draw other projections of the solid in more difficult positions.

Example 1.—Triangular prism $2\frac{1}{2}''$ long, base equilateral triangle, $1\frac{1}{2}''$ side (Fig. 21).

If the prism stand with one triangular face on the ground its plan will be an equilateral triangle, and may be drawn first. The elevation $a'\ b'\ c'$ of the face, which rests on the ground, will be on X Y; $a'\ b'$ and c' being projected from a, b, and c in the plan. The plan $d\ e\ f$ of the upper triangular face coincides with $a\ b\ c$. The elevation will be completed by drawing the elevation of the long edges $a'\,d'$, $b'\,e'$, $c'\,f'$, $2\frac{1}{2}''$ long.

Example 2.—Square prism, base $1\frac{1}{4}''$ side, $3''$ long.

Fig. 22 shows the plan and elevation when the square bases are parallel to the V.P. The elevation $a' b' c' d'$ should be drawn first—a square of $1\frac{1}{4}''$ side—in any position. The plan is drawn by taking

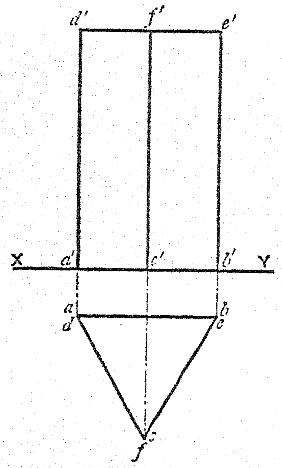


Fig. 21.

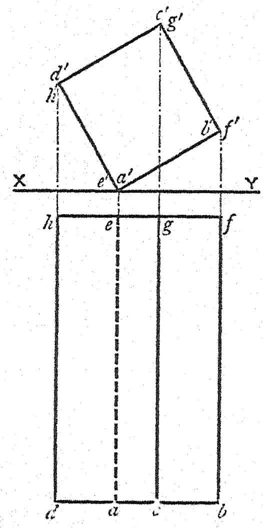


Fig. 22.

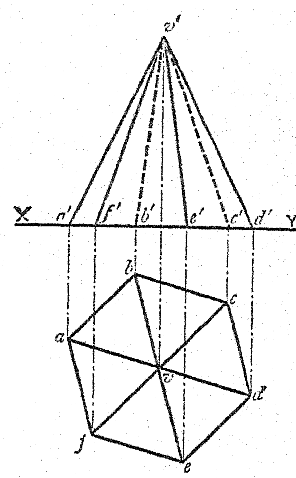


Fig. 23.

projectors from $a' b' c' d'$ at right angles to X Y, drawing the plan $a\,b\,c\,d$ of the front face parallel to X Y, and marking the plans of the long edges $a\,e$, $b\,f$, $c\,g$, $d\,h$, equal to 3″.

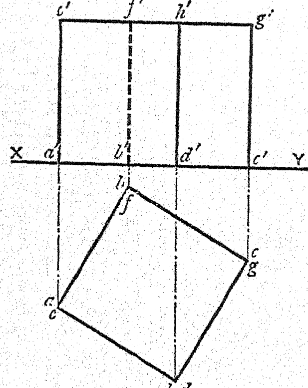


Fig. 24.

The elevation $e' f' g' h'$ of the back face coincides with the elevation $a' b' c' d'$ of the front face. If the prism is viewed from the top the lowest edge A E would be hidden; its plan $a\,e$ is therefore drawn dotted. Similarly, if when a solid is viewed from the front any line is hidden, the elevation of this line is drawn dotted (*see* $v' b'$, $v' c'$ in Fig. 23).

Example 3.—Regular hexagonal pyramid, base 1″ edge, height 2″. Suppose the hexagonal base to rest on the H.P., its plan will be a regular hexagon $a\,b\,c\,d\,e\,f$ (Fig. 23). The axis of the pyramid will be vertical, and therefore the plan v of the vertex V will be the centre of the hexagon $a\,b\,c\,d\,e\,f$. The elevation is got by taking projectors from $a\,b\,c\,d\,e\,f$ to X Y, and a projector from v, marking v' 2″ above X Y.

In viewing the pyramid from the front, the edges

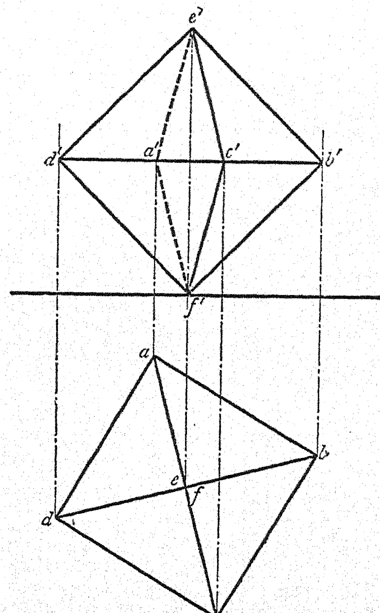


Fig. 25.

V B and V C would be invisible, the lines $v' b'$ and $v' c'$ in the elevation are therefore drawn dotted.

Example 4.—Cube $1\frac{1}{2}''$ edge. This is a particular

case of a prism, and can be drawn by the methods shown in Example 2. Note that $a'e' = ab$ (Fig. 24).

Example 5.—Octahedron 2″ edge. Considering

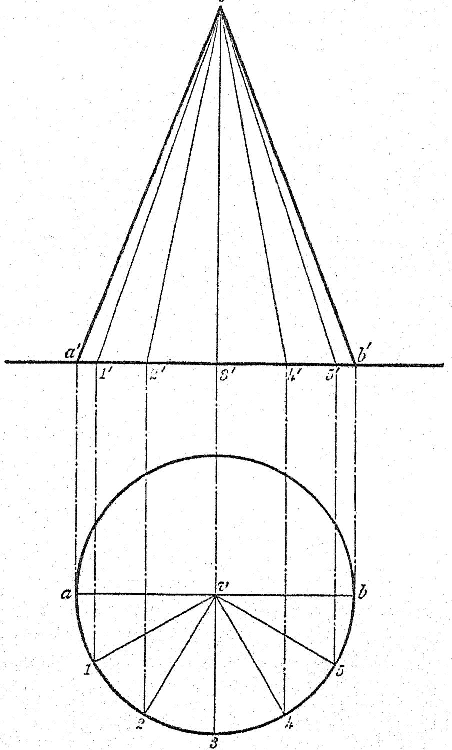


Fig. 26.

the solid as formed of two square pyramids set base to base, we may draw the plan $a\,b\,c\,d$, a square of 2″ edge; the two vertices E and F of the pyramid will be respectively above and below the centre of the square base. The plans e and f will coincide with the centre of the square. If the student study his model closely, he will see that this solid has three equal axes A C, B D, E F. Now we have drawn the solid in such a position that A C and B D are parallel to the H.P., and therefore $a\,c$ and $b\,d$ are each equal to the true length of the diagonal. The diagonal E F is also parallel to the V.P., its elevation $e'f'$ is therefore equal to the true length of the diagonal, *i.e.*, equal to $a\,c$ or $b\,d$.

The elevation of the solid is therefore drawn thus:—Project $c'f'$ from c or f and equal in length to $a\,c$ or $b\,d$. Bisect $e'f'$ by a line parallel to X Y, which will represent the elevation of the square base. From a, b, c, d on the plan, project a', b', c', d' to this line. Complete the elevation as shown in Fig. 25, taking care to draw the invisible lines dotted.

Example 6.—Right cone, base 3″ diameter, height $3\frac{3}{4}$″.

Fig. 26 shows the solid resting with its circular base on the H.P. The plan is a circle 3″ diameter, the plan of the vertex v is the centre of this circle. From a and b, the extremities of a diameter parallel to X Y, project a' and b' on to the X Y. From v draw a projector and mark on it v', $3\frac{3}{4}$″ above X Y. The triangle $v'\,a'\,b'$ will be the elevation required. Straight lines can be drawn on the surface of the cone passing through its vertex. In the figure a number of such lines are represented in plan and elevation.

Example 7.—Right cylinder, base 2″ diameter, length 3″.

If the circular base is parallel to the V.P., the elevation will be a circle 2″ diameter, and the plan a rectangle (Fig. 27).

The student who has carefully studied the above seven examples will have noticed that the solids are not strictly defined as to position relative to the co-ordinate plane. If certain conditions are specified, the student should take his model and place it in the proper position relative to the co-ordinate planes, before drawing plan or elevation.

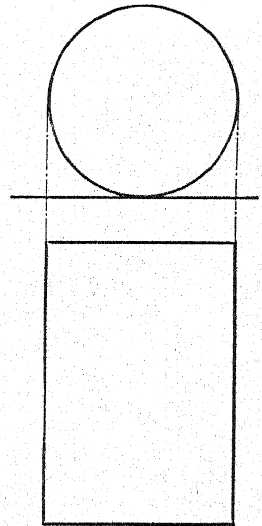


Fig. 27.

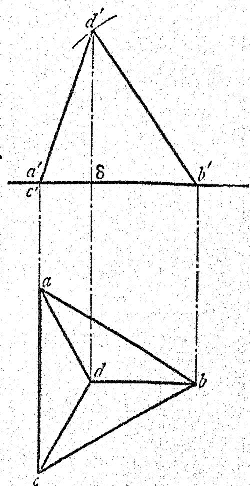


Fig. 28.

Figs. 21–27 are drawn representing the solids in the following positions:—

Example 1 (Fig. 21).—Resting with its base on the H.P. and a rectangular face parallel to and ½″ in front of the V.P.

Example 2 (Fig. 22).—With base parallel to and $\frac{1}{4}''$ in front of the V.P., one long edge in the H.P., and a rectangular face inclined 30° to the H.P.

Example 3 (Fig. 23).—With base resting on H.P., the corner nearest V.P. being $\frac{1}{2}''$ from it, and one edge of base inclined 15° to V.P.

Example 4 (Fig. 24).—With one face resting on H.P. and another inclined 30° to V.P, one edge $\frac{1}{4}''$ from V.P.

Example 5 (Fig. 25).—With one axis vertical and 2″ from V.P., and two axes horizontal and inclined 15° and 75° respectively to the V.P.

Example 6 (Fig. 26).—With base resting on the H.P., and axis $2\frac{1}{2}''$ in front of the V.P.

Example 7 (Fig. 27).—Resting on the H.P. with axis horizontal and at right angles to the V.P., bases $3\frac{1}{2}''$ and $\frac{1}{2}''$ respectively in front of the V.P.

Example 8.—Draw plan and elevation of a tetrahedron 2″ edge, when one face rests on the H.P. and one of the three sloping edges is parallel to the V.P. The plan will evidently be an equilateral triangle *a b c* of 2″ side, with lines going from *a*, *b*, and *c* to *d*, the plan of the vertex. From the symmetrical form of the solid, it is evident that *d* must be the centre of the triangle *a b c*. Also the plan of one of the sloping edges, as *b d* must be parallel to X Y, since the edge B D is to be parallel to the V.P.

The elevations *a′ b′ c′* of the three lower corners are in the X Y, and can be projected as shown. In the specified position of the solid *a′* and *c′* coincide.

Draw a projector from *d* and with centre *b′* and radius equal to *a b* draw a circular arc cutting this projector in the point *d′*; which will be the required elevation of the vertex D. Join *d′* to *b* and *a′ c′*. The elevation is now complete.

Let δ be the point where the projector *d d′* cuts the X Y then δ*d′* is the height of the tetrahedron.

In a regular solid the edges are all equal, and therefore in the tetrahedron the six edges are equal. We have chosen the above position of the solid, so that the true length of one of the sloping edges should be seen in the elevation *b′ d′*, and the height δ*d′* be thus easily determined. If the plan has been drawn with none of the lines *a d*, *b d*, *c d* parallel to X Y, a preliminary construction would be necessary to determine the height of the solid.

The woodcuts Figs. 21–28 are half full size of the given dimensions; the student, however, is recommended to draw out all these examples full size. He should actually *draw* all the examples given, and not be content with merely reading the text and glancing at the figures.

As a further exercise on the subject matter of this lesson, the solids represented in Figs. 21, 23, 24, and 25 may be drawn in such positions that there are fewer lines shown in the elevations.

CUTTING TOOLS.—II.

By R. H. Smith,
Professor of Mechanical Engineering, Mason's College, Birmingham.

[*Continued from p.* 20.]

CHISEL-TOOLS FOR WOOD.

Relations between Chisel-tools.—It is easy to recognise that there is some considerable resemblance and intimate relation between the modes of action of such tools as the iron wedge for splitting wood, the axe, the adze, the hatchet, the pen-knife, the paring and mortising chisels, and the spoke-shave.

Wedges.—This group of tools has been placed first on account of its comparative simplicity.

The iron or steel wedges used for splitting open logs of timber range from two to five inches wide, and in length up to six or seven inches. For harder woods they should have a gentler taper than for softer timber. The edge is ground to a much more rapid bevel than the general taper of the wedge. The object of this is evidently to obtain a moderately sharp taper without having a long, thin, weak part at the working extremity of the tool. Several wedges are inserted in the line of the split it is desired to make, the number used being proportioned to the breadth of the split. They are inserted by blows with a hammer, or, if the wood is too hard to permit this, a shallow saw-drift is sawn across the surface along the line of the intended split, and the wedges inserted in this. They are then driven in by blows from a hammer or axe, care being taken to distribute the blows along the row of wedges, so as not to let any one wedge be driven much farther in than any other at the same time.

While the rapid bevel of the extreme edge is entering, no splitting of the wood takes place (Fig. 1). A portion of the wood is simply crushed. The farther the point gets into the wood the wider is the area over which the tool crushes the wood beneath it, and the deeper does the crushing extend. It would thus be impossible to continue the large angle of bevel to any great distance from the point of the tool. This large-angled bevel must be very short, and beyond it must begin a much more finely-tapered part. This is the true wedge; and, as soon as it gets below the surface sufficiently for its sides to bear well against the timber, the splitting commences.

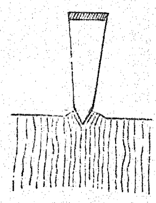


Fig. 1.

After the split has begun, the wedge bears against the top edges of the split surfaces. The arrows (Fig. 2) show approximately how it pushes

out the timber on either side. The two halves beyond the point to which the split has already extended cling together in opposition to the force of the wedge that seeks to separate them. Over the surface that is just about to split open, the left-hand half of the wood (marked A in Fig. 2) pulls the right-hand half, B, in the direction shown by the arrow 2.

We find, then, the block of wood, B, pushed to the right hand by a force represented by the arrow 1, and pulled to the left hand by another force lower down, represented by the arrow 2. It is thus clear that it must be kept in balance by a third force acting on it lower down than the arrow 2, and in the direction shown by the arrow 3. This force 3 can be exerted by nothing but the surface of the half-block A pressing against B in the direction of the arrow 3. While, therefore, the action of the wedge makes the two halves of the block pull away from each other at about the level of the arrow 2 (*i.e.*, throws the timber into *tension* in this part of it), it simultaneously causes the lower portions to push against each other—that is, it throws them into *compression*.

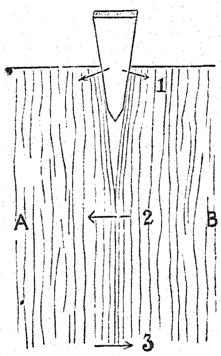


Fig. 2.

It is evident that the tension is greatest close below the last point at which the two split surfaces have actually separated. From this point downwards the intensity of the tension decreases gradually, until at a certain level it has diminished to nothing. Here the wood is neither in tension nor compression, and beyond this position downwards the compression gradually increases from zero to a maximum intensity at some level depending on the length of the block. The compression then diminishes again the farther one goes from the extremity of the split.

The length over which the wood is thrown into tension by the action of the wedge depends altogether upon the curve to which the splitting surface of the half-block is bent. The rounder this curve is the shorter becomes the length of wood thrown into tension, and conversely. The block will bend to a sharper curve the softer and more pliable the kind of timber is. The curve will be straighter, on the other hand, the thicker the block is from the line of the split to its outer surface on the right hand. Now the whole pull, indicated by arrow 2, is roughly proportional to this length over which tension is distributed, because the intensity of the tension per square inch of surface increases gradually from zero at the lower end of this length up to just that amount at its upper end necessary to tear one surface quite away from the other. This last maximum intensity of tension is the same for different blocks of the same kind and quality of timber. It is simply the measure of the direct tensile strength of the wood across its grain. The stiffness of the wood, on which depends the straightness of the curve and the length of the surface over which tension is caused, is measured by the modulus of elasticity. As for the exact ratio in which the pull that the two halves exert on each other in clinging together varies with the above-mentioned elements, an approximate theoretical calculation can be made, and this shows that (other things being equal) this pull is proportional to the fourth root of the modulus of elasticity and to the fourth root of the cube of the product of the tensile strength by the thickness from the split to the outside surface.

That is, if $E =$ Modulus of elasticity,

$T =$ Tensile strength in the direction transverse to the split,

and $h =$ thickness from split to outside surface, then the pull represented by arrow 2 is proportional to $\sqrt[4]{ET^3h^3}$.

It varies also, of course, in simple proportion to the width of the split.

This force 2 is balanced by the forces 1 and 3 together. The portion of it balanced by 1 decreases as the distance from 2 at which 1 acts, that is, the length of the split, increases. The same approximate calculation as is referred to above shows that, roughly speaking, it varies inversely nearly in proportion to the length of the split, and at the same time varies directly in proportion to $\sqrt[2]{ETh^3}$. Taking the last term of this expression separately, it is seen that the transverse force which the wedge exerts on the edge of the wood increases in the ratio of the square root of h^3 or the thickness of the piece split off; that is, it increases in a faster ratio than this thickness but not so fast as its square. If, however, the split be extremely short, the point of the tool following close to the point of actual separation of the material, and the pressure of the tool being exerted close to its edge, then this pressure varies more nearly with the $\frac{3}{4}$ths power of the thickness of the shaving; that is, not quite so fast as that thickness.

Wedge-Action in Cutting Tools.—The object of explaining so minutely the action of a wedge in splitting a block of wood will be soon seen, when we find that an important part of the action of all

cutting tools is quite similar to that of the simple wedge. The results of the above investigation will serve to explain many points which are, at first sight, and taken by themselves, difficult to understand, but in the elucidation of which no time need be lost, now that a clear comprehension of the effect of the simplest of all tools has been gained.

It is to be remembered that the wedge acts in two ways. At first, when the sharp-pointed edge is entering, it causes no splitting, but simply crushes and pushes aside the small quantity of material in close proximity to its edge and into which it penetrates. After it has got a certain distance, it begins to cause a split in advance of its edge, in the manner described in detail above.

Mortising Chisel.—Of the tools belonging to this first group, that which bears the most resemblance to the simple wedge in the mode of its action is the common mortising chisel. It also is driven forward by blows from a hammer, and the thicknesses of the pieces of wood removed by it being large, it acts to a great extent by splitting. Its edge, however, is made much finer and sharper to give more penetrative capacity, in order that it may cut the fresh surface clean and smooth (in a manner that will be presently explained), and because also it is used to cut transversely to the grain of the wood, in which direction the wood both yields to the penetrating edge and also splits with much greater difficulty than in the direction of the fibre. The fine edge is, of course, more liable to be broken by the shocks of the blows than that of the common wedge, and, therefore, a wooden hammer or mallet is used in order to mitigate the violence of the shocks. One other difference is that the one surface of the mortising chisel is made quite flat, the bevel which makes the extreme edge being put all on one side. This flat surface acts as a guide whereby the tool may be advanced through the wood in a straight line, cutting off all the material lying on one side of that line. The mortising chisel is used as a hand tool, but also as a machine tool. In this latter form the chisel is fixed in a socket attached to a slide driven down and up guide-surfaces in the frame of the machine. The driving is accomplished either by hand or by power.

Axe.—The ordinary woodman's axe (Fig. 3) has both sides rounded off equally, there being no flat bevel on either. This allows the workman with greater facility to cut into the wood at any angle he may desire to the surface upon which he is working. The surfaces being rounded so prevent him from obtaining accurate flatness in his work, but for his purpose this is of no consequence. The handle, or shaft as it is called, should be of straight-grained ash, and is made from 3 to 4½ feet long. The workman swings the axe round with the full stretch of his arms so as to bring it to the greatest

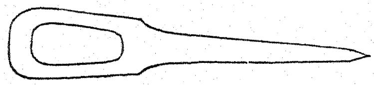


Fig. 3.

possible velocity at the moment of striking into the timber.

The shaft is made oval, the greatest diameter being in the plane of the blade. The shock of the blow being in this plane, the strength of the shaft to resist breakage requires also to be in the same direction. As great a depth as can be conveniently grasped in the hand is, therefore, given in this plane. By making the transverse thickness smaller this depth can be made greater, because the size that can be firmly grasped in the hand depends more on the length of the circumference than on the diametral size, the fingers accommodating themselves to any desired shape. The oval section also allows the workman to know by the feel in what position he has hold of the axe, and so to direct it that the edge may fall on the wood at the desired angle.

Hatchet.—The hatchet has a short straight shaft, and can be wielded with one hand. What is called a side hatchet has the thickened head for the reception of the shaft end lying all to one side, so as to leave one side quite flat. No bevel is put on the edge on this side, the bevel being wholly ground from the other side. This is used for flattening the vertical sides of posts, etc., but is not a good tool for the purpose.

Adze.—The adze has a blade which stands perpendicular to the shaft and to the plane in which it is swung. The blade, as shown in Fig. 4, is curved in the direction in which it is swung. This allows the blade to lie flat down on the surface which is being worked, and thus act as a guide to the advance of the cutting edge; and at the same time allows the end of the shaft to clear the surface of the timber. It also allows the tool to be heeled over slightly after being driven into the wood, so as to

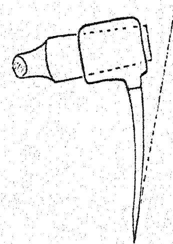


Fig. 4.

break off the shaving that has been cut. The sharp end is made by grinding one bevel only, which is on the inside, that is, away from the timber being cut. If the outside is quite straight crosswise, and regularly curved, this tool is capable of producing very true flat surfaces. It is used both with a long

shaft, swung with both hands, and with a short one held in one hand only. In using the long-shafted adze the workman stands on the log to be cut, which is laid horizontally, and makes the cut either between or directly in front of his feet.

Pen-knife.—The pen-knife is in every respect similar in form of cutting edge and in action to the axe with a two-bevelled edge, except that it is driven into the material to be cut by a steady pressure, not by a blow. Being rounded on both

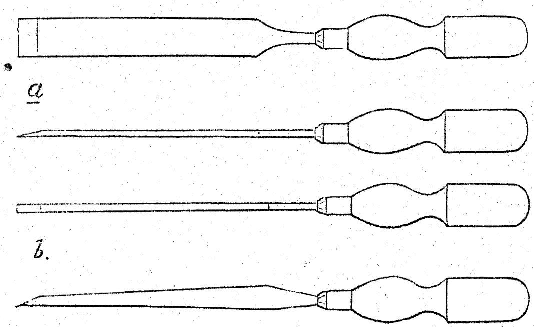


Fig. 5.

sides, it is incapable of producing truly flat surfaces.

Paring Chisel.—The most perfect instrument of the sort now being described for cutting wood is the ordinary paring chisel. These chisels are made from 6 to 10 inches long, and from $\frac{1}{8}$th of an inch to 2 inches wide. In order to give sufficient strength, the very narrow ones are made extra thick, as shown in Fig. 5, *b*. The length is made greater for the larger widths, but in consequence of frequent re-grinding and re-sharpening, broad chisels of very short length are as often met with in the workshop as narrow chisels are.

In the process of manufacture both faces of the chisel are ground. One of these is ground very carefully flat. The other side is ground to a bevel at the edge, the angle between the bevel and the flat face being about 30°. In cutting vertically the wood to be cut is steadied in its position on the bench by the left hand, and the chisel handle is grasped by the right hand. The left shoulder is placed on the top of the chisel handle, and pushes it forward, while the right hand guides and steadies it, the flat face of the blade being always kept towards the workman.

In paring horizontally the wood is fixed in the vice or on the bench, the blade of the chisel is grasped and guided by the left hand, and its wooden handle is driven forwards by the pressure of the right hand.

In sharpening the chisel on the oil-stone, some workmen lay the bevelled surface flat down on the stone, so that the whole surface is rubbed on it, but the more common custom is to rub only a small facet, making, with the flat face, an angle 5° or 10° greater than that of the ground bevel. If the chisel has been ground carefully to a fine edge, the first method may be followed with great advantage at the first setting on the oil-stone, but in subsequent re-settings much time is lost by doing so, because of the large surface to be rubbed down. Whatever be considered the proper angle for the facet, it is easy to grind the bevel to an angle smaller than it by a few degrees, and thereby to secure a small sharpening surface on the facet. The advantage of rubbing down the ground bevel at the first setting seems to consist in providing a smooth surface over which the shavings may slide, whereby less force is required to shove the chisel onward. It costs but little trouble to smooth away the roughness of the grinding, because these, instead of constituting a complete unbroken surface, are actually merely projections scattered here and there, the total area of which bears a small ratio to that of the surface on which they stand. The first edge, prepared in this way, stands undulled a considerably longer time than the subsequent edges with the larger facet-angle do.

DRAWING FOR CARPENTERS AND JOINERS.—II.

[*Continued from p.* 28.]

PENCIL DRAWINGS (*continued*).

Example 4.—Fig. 16 is the section of a wall of planks which confines soil subject to the action of water. This form of wall is used in cases where the soil is very swampy in character, or where the external water might pass through fissures in the bed of the stream, and so disturb foundations built on the soil.

The piles *a* are 12″ square in section, and are placed 5 feet apart. They are connected by the cross timber *d*, which is notched 2″ deep to receive the piles, and which rests on the bed of the water. The piles are also connected by the cross timber *b* near their upper ends. Sheet piling *c* of planks 8″ × 4″ are driven down into the bed of the water, and then a strong rail *e* 6″ square is placed at the back of them and a $1\frac{1}{4}$″ bolt, passing through *e*, *c*, *b*, and *a*, binds them all firmly together.

Draw the section Fig. 16 to a scale of half an inch to a foot, and draw also a longitudinal elevation showing four or five piles; draw also a plan. The three views to be properly projected from each other, compare Figs. 3, 4, and 5.

Example 5.—Fig. 17 is a section of a simpler kind of wall than that shown in Fig. 16. The piles *a*

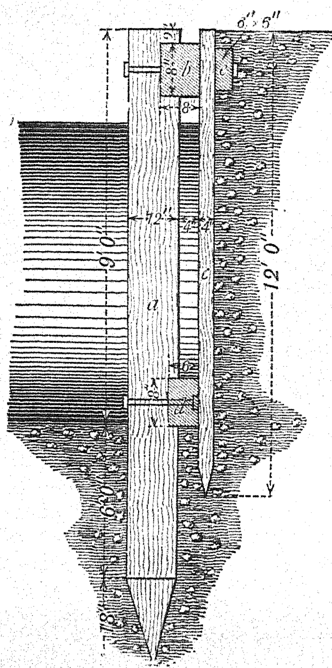


Fig. 16.

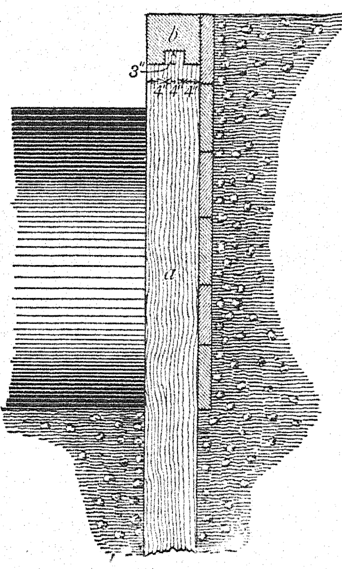


Fig. 17.

are of the same dimensions as in Fig. 16, the planking is horizontal, and rests directly on the back of the piles. The piles are united at the top by the cross timber *b* into which they are mortised.

Draw the views corresponding to those in Example 4—viz., section, longitudinal elevation, and plan. Scale, ½ inch to a foot.

Example 6.—Fig. 18 is a section and Fig. 19 an elevation of the wall of a coffer-dam. A coffer-dam is a water-tight wall enclosing the site on which the pier of a bridge, or other structure surrounded by water, is to be erected. They must, of course, be made strong enough to bear the pressure of water from without. The coffer-dam illustrated in Figs. 18 and 19 is constructed by three rows of piles *a, b, c*; the two rows nearest the water *a* and *b* being of the full height of the coffer-dam and the third *c*, being half the height. In the example under notice the piles are 12″ square in section, and are spaced 5 feet apart. The distance between the rows is 6′ 0″. The piles are united at the top and near the middle by cross timbers d_1 and d_2, 9″ square in section, placed one on each side of the piles; notched, and having a 1¼″ bolt passing through the three timbers. (*See* Fig. 20.) The row of piles *c* are connected in a similar manner by the cross timbers *e*. Resting on these, timbers *f*, 9″ × 6″, are laid across in pairs, one timber on each side of the piles, and a 1¼″ bolt passes through the three timbers, uniting them securely. An inclined stout pile *g* is also fastened in the same way to the timbers *f*; and at the top to the pile *b* by the wooden key and iron strap shown in detail (Fig. 21). The transverse timbers *h* at the top of the long piles are notched down on the longitudinals *d*. The space between the piles is filled in by sheet piling *k* driven down between the longitudinals d_1, d_2, and *e*.

Lastly the space between the rows of piles is filled with clay well rammed to make the wall watertight.

With regard to the struts *g* in the above example, Tredgold says, "Struts in the body of the dam at a level much below high water are objectionable, as they would hinder the packing of the puddle, and be a fruitful source of leakage afterwards,

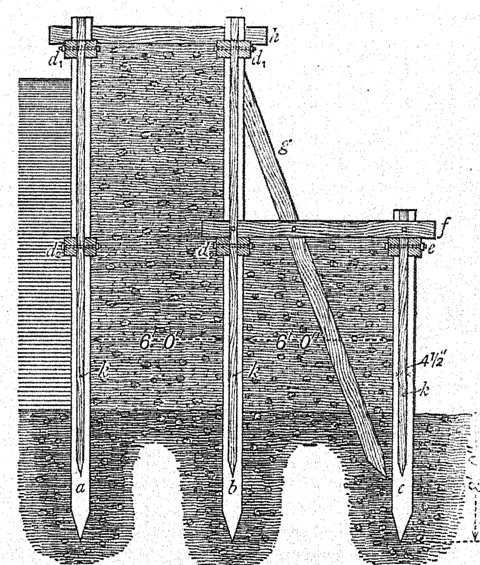


Fig. 18.

from the water creeping along them and causing the puddle to settle."

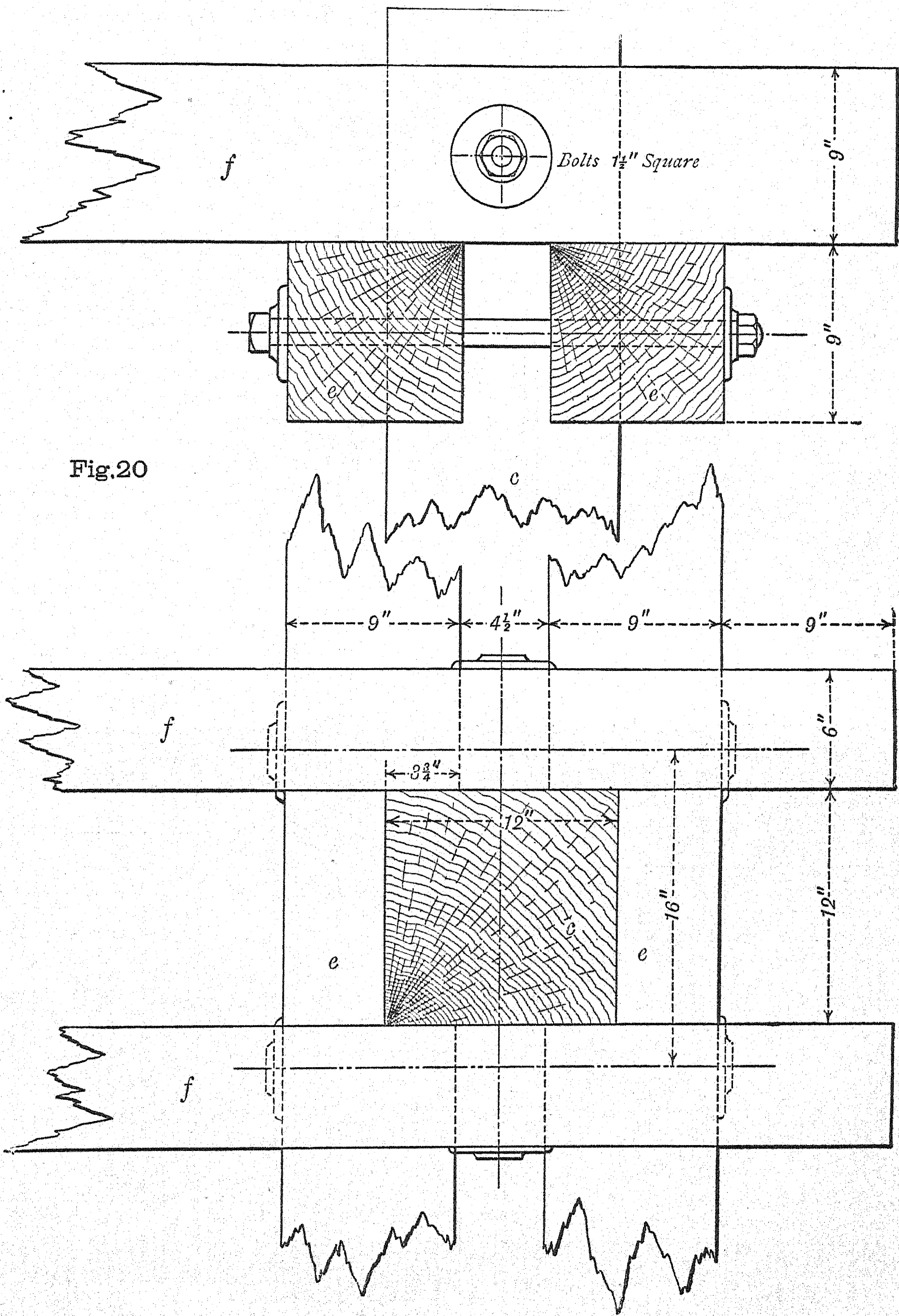


Fig.20

Draw the views shown in Figs. 18 and 19 half-inch to the foot. In order to make a thoroughly

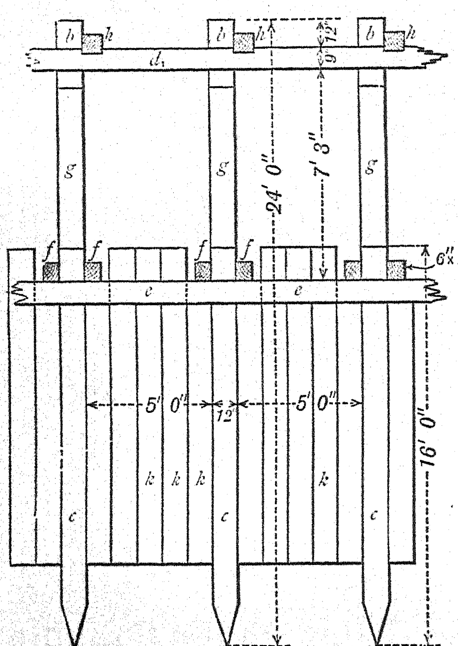


Fig. 19.

good working drawing, detail drawings of the various joints should be made. Fig. 20 shows such a detail drawing of the joint at the top of the row of piles *c*. The position of bolts is indicated by the centre lines and by the washers drawn in position; the student may complete the drawing of the bolts. Fig. 21 is a drawing of the joint of the strut *g* and pile *b*. Draw also details of the joint at the top of the long piles *a* and *b*. These detail drawings should be to a fairly large scale, say 3″ to a foot.

Example 7.—Fig. 22 shows a section of a simpler coffer-dam. Taking the timbers of the same section as in Example 6, make a series of drawings similar to Figs. 18, 19, and 20. The piles *a* are united at the top by a longitudinal *b*, a tongue on the end of the pile being fitted into the longitudinal; cross timbers *c* are notched down on the longitudinals, thus preserving the distance between the two rows of piles. The planking *d d* is horizontal, and rests against the inner sides of the piles. Draw the example with the piles driven 8 feet into the soil, and with a distance of 10 feet from the top of the transverse timber *c* to the surface of the soil. Scale, half-inch to a foot.

In the above examples the piles are marked with a definite length buried in the soil. These figures must be regarded as approximate. In practice the piles are driven until they have got a firm hold of the soil, the tops are then sawn off to the same level. Piles from 10 inches to 14 inches are driven by a "monkey" weight of 1,000 to 1,700 lb. Sheet piles 8 or 9 inches wide and 3 or 4 inches thick require a weight of 500 to 900 lb. Figs. 23*a* and 23*b* show a "monkey" and its guide post; the monkey is shown resting on the top of a pile, it is lifted by a crane, and when at a convenient height is let fall on the head of the pile, being guided in its descent by the guide-post. The monkey weight, or rammer, is made of beech or other hard wood, and is bound by iron straps as shown.

A coffer-dam used in the construction of the Alexandra Dock, Hull, was "461 feet long, constructed of two rows of piles 6 feet apart, with clay puddle between, the piles being 50 to 60 feet long, and driven about 33 feet into the ground, the main

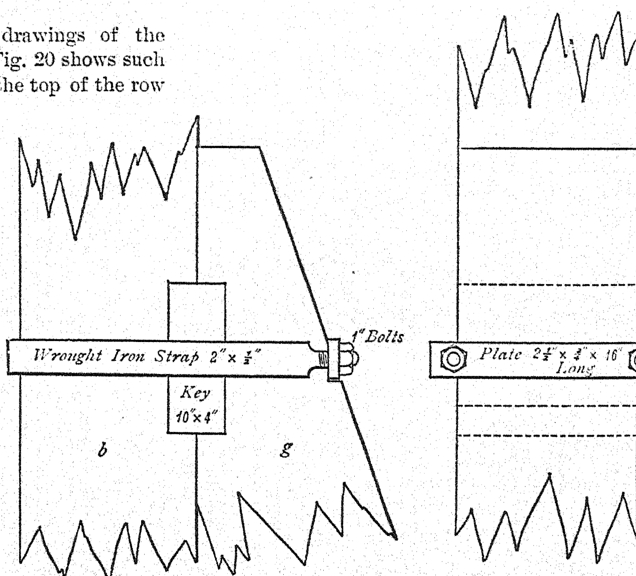


Fig. 21.

piles reaching down to 54 feet below high water. It was commenced in July, 1881, and completed in

June, 1882, and contained 67,702 cubic feet of

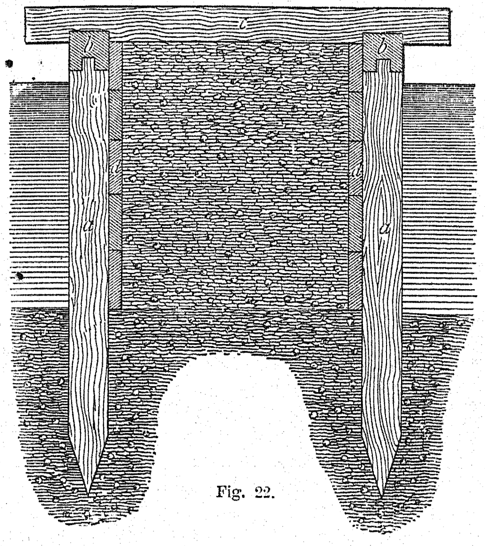


Fig. 22.

timber. The piles were mostly pitch pine or Memel, and several of the main piles required 30 to 40 blows of a 1-ton monkey falling 8 feet to drive them an inch. The maximum deflection of the dam was 3 inches, from external pressure at the centre." The two rows of piles were connected by a series of 2″ bolts. The foregoing information is from a paper by Hurtzig published in the Transactions of the Institution of Civil Engineers, Vol. 92.

The following practical hints are by Mr. Dobson: "Leakage between the puddle and the surface of the ground will generally take place unless all the loose, soft, or porous surface soil be removed by dredging before the puddle is put in. The framing and strutting should be sufficiently strong to prevent any straining or movement under the varying pressure to which the dam may be exposed by alternations in the height of the water; and lastly, the material used for the puddle should be such as will settle down into a solid mass, and should be carefully punned in thin layers so as to secure that no vacuities are left in any part. The tie-bolts used to connect the inner and outer rows of piles are often found to be very troublesome sources of leakage, as the water soaks in round the bolt-holes and it is difficult to keep the puddle from settling away from the bolts, and leaving a channel for the passage of water through the dam."

Fig. 23 *a*.

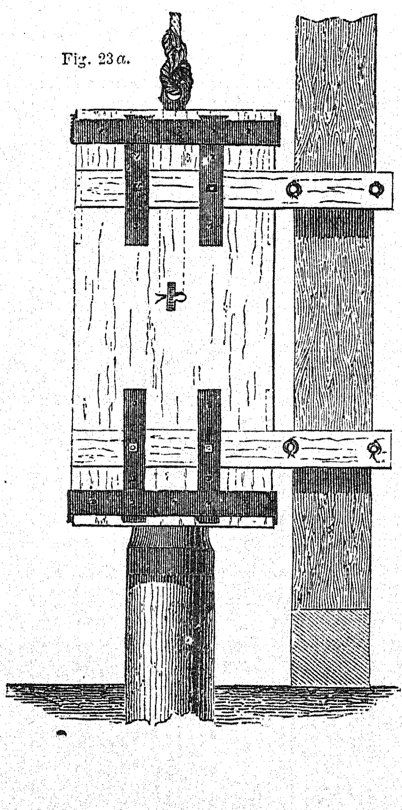
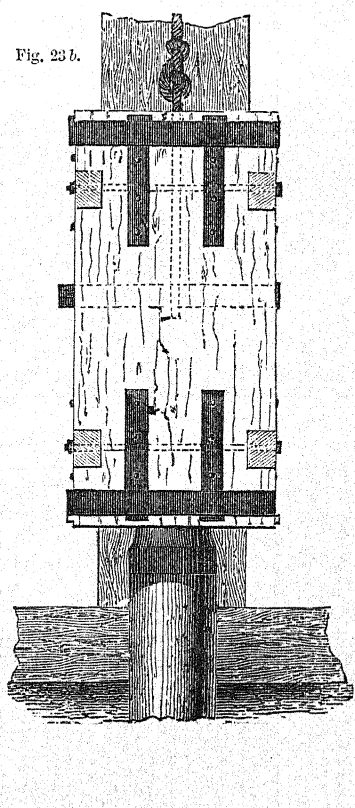


Fig. 23 *b*.



WATCH AND CLOCK MAKING.—II.

By David Glasgow,
Vice-President of the British Horological Institute.
[*Continued from p.* 40.]

TRAINS.

The train of wheels in a watch or clock is the method of applying and the medium for regulating and distributing the power from the prime mover to the escapement, which regulates the speed.

The power exerted by wheels on pinions is inversely proportional to the relative diameters of their pitch circles, and they may for purposes of calculation be considered as a series of levers, the centres being the fulcrums and the acting part of each tooth at the line of centres being their effective length.

The importance of taking the resistance of trains into consideration is continually exemplified in the absurd clocks which are frequently constructed to go for six months, or a year or so, without rewinding, but which never do go even when much heavier weights or stronger springs than the original are put to them, and the only cure for which is to increase the leverage by changing some of the wheels and pinions, or by increasing the size of the barrels, which of course shortens the time of their going.

The trains of wheels used in modern English watches are the 18,000, the 16,200, and the 14,400, so called because of the number of vibrations made by the balance in the hour. The total number of vibrations made by the escapement of a watch or clock before the power is expended is dependent on the relative number of teeth in the wheels and pinions. The time of the vibrations is regulated by the balance spring or by the pendulum.

The 16,200 is the train nearly always used here in lever watches, and the 18,000 in pocket chronometers and duplex escaped watches. The Swiss generally use the latter train in all their watches, it being better adapted for their frictional cylinder escapement, with its short vibrations; indeed, for any escapement where the watch is without the fusee adjustment, the unequal pull of the mainspring is less felt with the quick train than with the slow one. The falling off in the arc of vibration, consequent on the mainspring unwinding itself, with a 16,200 train with the going barrel, is fully a quarter of a turn in the twenty-four hours, and the watch loses as the power decreases; this difference is not so great and does not affect the going of the watch so much with the 18,000 train, the balance spring being relatively stronger, and this train is accordingly used in nearly all foreign watches that are not intended to be sold as of English make. On the other hand, with the fusee adjustment, the arc remains constant throughout the time of going of the watch, and the balance of power between the balance and its spring being enabled to be better maintained with the 16,200 train, this train is accepted as the best for English lever watches. In all old watches lower-numbered wheels and pinions will be found than are at present used. When, however, the lever escapement became general, higher numbers were employed, but with slower trains (of somewhere between 14,000 and 15,000 vibrations in the hour).

These slow trains are never now used in pocket watches, as it is found that as the balance moves slowly, the spring is consequently weak in proportion to its weight and diameter, and does not sufficiently control the movement of the balance, so that any irregularity in the force transmitted from the mainspring to the escapement is very much felt, and has an effect on the length of the vibrations. In addition to this, the jars and motions to which a watch is subjected when in use check or accelerate the vibrations to a greater extent than if the spring were proportionally stronger.

In the best watches, with what are known as high-numbered movements, the train used is as follows:—

	Great Wheel	Centre	Third	Fourth	Escape
Wheel . .	84	80	75	72	15
Pinion . .		12	10	10	8

The large majority of English watches have the following train:—

	Great Wheel	Centre	Third	Fourth	Escape
Wheel . .	75	64	60	63	15
Pinion . .		10	8	8	7

Though I prefer and always use in watches of an inferior quality:—

	Great Wheel	Centre	Third	Fourth	Escape
Wheel . .	84	64	60	63	15
Pinion . .		12	8	8	7

It has been shown that there would be a great advantage in using pinions of even higher numbers than it is possible to employ in watches, and it costs very little more to make a pinion with ten leaves than to make one with eight; but "high numbers" are usually a distinctive feature of a movement of superior quality.

In small watches where the high numbers would greatly reduce the size of the teeth, the lowest numbers given above are found the best, as great accuracy is not often sought for, nor is it attainable, in watches of very small size. In watches with the chronometer and duplex escapements the 18,000 train is used. I have seen Swiss watches with even a faster train, but such watches are wrong in principle, as the balance must be necessarily

made very small and light, and the balance spring must be disproportionately strong.

It has been thought by some watchmakers that as the balance in these escapements receives the impulse only at alternate beats, the vibrations should be quicker, but a much better reason for applying a fast train to these watches is, that if there is not what is called a "banking" to check the balance in case any external motion or jerk causes it to exceed its normal arc of vibration sufficiently to allow of several of the escape wheel teeth passing the pallet at once, what is termed "tripping" will take place, and the watch will run half a minute or so in a few seconds, and this is not so liable to occur with the quick train on account of its shorter vibrations.

Ships' chronometers are constructed with trains of 14,400, giving four beats per second, and as, like the pocket watch with this escapement, the impulse is given at alternate beats, the seconds hand moves at every half-second.

The seconds being thus evenly divided, it is much easier to ascertain the true time or to take the rate, either by observing the seconds hand or by listening to the beats, with one of these instruments, than with a pocket watch in which the seconds are unequally divided; and as ships' chronometers are always kept in a horizontal position by being hung in gimbals, and are not subjected to such outward disturbing influences as watches, the vibrations are not interrupted, and there is not the same necessity for having a faster train.

The movement of a marine chronometer being precisely similar to that of its prototype, the watch —save that there is proportionally more room—it allows of a higher-numbered train. Those now constructed are mostly what are called "two-day" chronometers, and go for fifty-six hours without re-winding, the train usually adopted being—

	Great Wheel	Centre	Third	Fourth	Escape
Wheel . .	90	90	80	80	15
Pinion . .		14	12	10	10

The only difference between the "eight-day" and "two-day" chronometers is in the length of time they will go without rewinding; hence their trains differ only in the number of teeth and leaves in the great wheel and centre pinion, and the turns made by the chain on the fusee.

In calculating the train of wheels of a watch or clock, all that we have theoretically to consider is the ratio of speed of the first or great wheel to the last or escape.

The two facts that regulate the relation of the numbers of teeth and the rates of revolution of the wheels of a train are the following: (1) the number of turns in a given time for a wheel and pinion on the same axis is the same; (2) for wheels that are geared together, the same number of teeth in both pass the same point in a given time; hence the product of number of teeth in the wheel by number of turns in a given time is the same for both.

Let E, e stand for number of teeth in wheel and pinion.

Then the train is represented by

$$\begin{array}{cccc} E_1 & E_2 & E_3 & E_4, \\ & e_2 & e_3 & e_4 & e_5. \end{array}$$

As we are concerned only with the number of revolutions of the wheels from the centre E_2 to the pinion e_5, we may represent these numbers thus:—

$$\begin{array}{c} E_1\, e_2\, E_2\, e_3\, E_3\, e_4\, E_4\, e_5, \\ T_1\, T_1\, T_2\, T_2\, T_3\, T_3\, T_4. \end{array}$$

Applying the second of the above rules to these symbols, we have the following equations:—

$$T_1 E_2 = T_2 e_3 \,;\; T_2 E_3 = T_3 e_4 \,;\; T_3 E_4 = T_4 e_5.$$

Multiplying the equations together, we obtain:—

$$E_2 E_3 E_4 T_1 = e_3 e_4 e_5 T_4.$$

Hence $\quad T_1 : T_4 :: e_3 e_4 e_5 : E_2 E_3 E_4.$

Or the result may be otherwise expressed, as follows:—

To ascertain the ratio of the number of turns in a given time between any wheels in a train, multiply together the number of teeth of the slowest with that of every intermediate wheel, and divide the product by the number of leaves in the fastest and all the intermediate pinions multiplied together. Example: Required the ratio of speed between a centre wheel of 80 teeth (where the third has 75 with a pinion of 10, and the fourth has 72 with a pinion of 10), and the escape wheel with a pinion of 8. Then

$$80 \times \frac{75}{10} \times \frac{72}{10} \times \tfrac{1}{8} = 540,$$

which is the ratio required, the escape wheel turning 540 times to once of the centre wheel; and this number multiplied by twice the number of teeth in the escape wheel will give the number of beats made by the escapement in the hour,—the number of beats being determined by the velocity ratio between the centre and escape wheels, and the length of time the watch will go by the number of teeth in the great wheel, the leaves in the centre pinion, and the number of turns made by the barrel (if a going-barrel watch) or by the chain on the fusee.

Take the first of the trains given on page 92, and let it be required to find the number of turns made while the centre wheel turns once:—

$T_1 E_2 = T_2 e_3$ gives $1 \times 80 = T_2 \times 10$, or $T_2 = 8$.
$T_2 E_3 = T_3 e_4$ gives $8 \times 75 = T_3 \times 10$, or $T_3 = 60$.
$T_3 E_4 = T_4 e_5$ gives $60 \times 72 = T_4 \times 8$, or $T_4 = 540$.

Again, suppose we know that the ratios of the numbers of turns are as 1, 8, 60, 540, and also that the number of teeth in the escape pinion is 8, then we can find the number of teeth in the other wheels thus:—

$$T_3 E_4 = T_4 e_5 \text{ gives } 60 \times E_4 = 540 \times 8, \text{ or } E_4 = 72,$$

and so on.

To find the number of teeth of an intermediate wheel:—The number of turns made by the required wheel: the number made by the next faster: : the number of leaves in the next faster pinion: the number of the wheel required.

Example.—Find the number of teeth in the fourth wheel in the first of the foregoing trains, having given the number of turns in the last two, and number of teeth in escape pinion:—

Then $60 : 540 :: 8 : x$

$$\frac{540 \times 8}{60} = 72, \text{ the fourth wheel required.}$$

To find the number of the third wheel pinion:—Multiply the number of teeth in the wheel by its number of revolutions, and divide the product by the number of revolutions of the fourth wheel.

Example: $\frac{75 \times 8}{60} = 10$, the third pinion required.

To find the number of the fourth wheel pinion:—Multiply the number of teeth in the fourth wheel by the number of teeth in the third, and divide by the number of revolutions of the escape wheel.

Example: $\frac{72 \times 75}{540} = 10$, the fourth pinion required.

To find the number of the escape wheel pinion:—Multiply the number of teeth in the fourth wheel by its number of revolutions, and divide by the number of revolutions of the escape wheel.

Example: $\frac{72 \times 60}{540} = 8$, the escape pinion required.

To find the number of turns a barrel or fusee should make in order to allow a watch to go for a certain number of hours (say thirty):—Multiply the number of leaves in the centre pinion by the number of hours required, and divide by the number of teeth in the great wheel.

Example: $\frac{30 \times 12}{84} = 4\frac{2}{7}$, the required turns.

This is the shortest way; but the usual method adopted by finishers is to divide the number of teeth in the great wheel by the number of leaves in the pinion, and to divide the number of hours required by the quotient.

Example: $84 \div 12 = 7$; and $30 \div 7 = 4\frac{2}{7}$, the required turns.

To find the number of great wheel teeth:—Multiply the number of the centre pinion leaves by the number of hours the watch is required to go, and divide by the number of turns made by the fusee or barrel.

Example: $\frac{12 \times 30}{4\frac{2}{7}} = 84$, the number of teeth required.

To find the number of centre pinion leaves:—Multiply the number of the great wheel teeth by the number of turns of the fusee or barrel, and divide by the number of hours the watch is required to go.

Example: $\frac{84 \times 4\frac{2}{7}}{30} = 12$, the centre pinion leaves required.

To find the number of hours a watch will go:—Multiply the number of great wheel teeth by the number of turns of barrel or fusee, and divide by the number of centre pinion leaves.

Example: $\frac{84 \times 4\frac{2}{7}}{12} = 30$, the hours required.

Motion Wheels.—The wheels that carry the hands are called the motion wheels, and consist of the cannon pinion, the hour wheel, and the minute wheel and pinion.

The minute wheel and its pinion have nothing to do with the carrying of the hands, but are simply intermediate between the cannon pinion and the hour wheel, for the purpose of regulating the speed of the latter, which is as 1 of the hour wheel to 12 of the cannon pinion. They rotate on a stud, which is screwed into the plate in the plane of the wheel and pinion with which they gear, and are usually kept in their place by the dial of the watch.

The hour wheel turns on the cannon pinion, and carries the hour hand, and the cannon pinion carries the minute hand.

In a full plate watch the cannon pinion is fixed to the arbor of the centre wheel by being snapped, or sprung on, sufficiently tightly to carry the hand, but not to prevent it from being turned on the arbor when the hands are being set. The square upon which the hand is fitted is left projecting a little, so that a key may be applied to it for this purpose.

In a three-quarter plate movement the centre pinion is hollow, and what is called the set-hand piece goes through it, and has the cannon pinion pushed tightly on the projecting part of it. This piece has a square at the other end of it which enables the watch to be set from the back, but this point I shall notice more fully farther on.

As the motion pinions are always acting as drivers (except during the short time of setting the hands in keyless watches, which is not worth considering), they should be sectored large and have epicycloidal teeth, and the cannon pinion should always be as large as possible, in order to allow of its being properly turned out at the back to free the centre stopping, which is left projecting, and, as there should be no shake, the minute wheel and its pinion should be pitched as deeply as possible, consistent, however, with ensuring perfect freedom of gearing, the motion wheels in some Swiss watches being pitched so deeply that they will not run at all.

The following are very good and convenient numbers for motion wheels:—

Cannon pinion	14
Hour wheel	48
Minute wheel and pinion	42 and 12.

For smaller watches:—

Cannon pinion	12
Hour wheel	40
Minute wheel and pinion	36 and 10.

The numbers used in ships' chronometers are:—

Cannon pinion	14
Hour wheel	54
Minute wheel and pinion	56 and 18.

The cannon pinion in these chronometers is snapped on to the arbor of the centre wheel in the same way as in a full plate watch. This is also a very good plan for keyless watches, where the hands are set from the pendant through the motion wheels, as the centre pinion and arbor may thus be left solid. In these watches the minute wheel should be made of steel and cut with fewer teeth for strength.

To find the number of the motion pinions:—Multiply together the numbers of teeth of the minute and hour wheels, and divide the product by twelve (the ratio of the turns between the hour wheel and the cannon pinion) and the result will be the same as the product of the numbers for the two pinions multiplied together. Thus, by dividing the number obtained by the number for either pinion, the quotient will be the number for the other.

In contriving a train for the motion work, it is only necessary to remember that the product of the numbers of the wheels multiplied together must be twelve times that of the numbers of the pinions multiplied together.

THE FUSEE AND MAINSPRING.

The Fusee.—The fusee is a brass cone mounted on an arbor, and its use is to equalise the pull of the mainspring, which is greater when wound round the barrel arbor than when it has expanded round the inner circumference of the barrel. It has a spiral groove cut on it to hold the chain and to keep it on its edge, and is much larger at one end than the other; when the spring is wound up by the chain being wound on to the fusee and is pulling most, the pull is first exerted on the smaller end of the cone, and as the spring unwinds and gradually pulls less, the leverage on the cone increases, the rate of increase being such as constitutes a perfect adjustment of the mainspring.

Without Harrison's maintaining power, the fusee would not have been of much advantage to watches that were required to keep correct time, as the act of winding takes the power of the mainspring from the great wheel, and the watch would either go backwards or stop altogether while being wound.

Fig. 3 shows the fusee and barrel in elevation with chain attached (partly on each); it also shows the position of the hooks by which the chain is attached.

Fig. 4 represents the separate parts of the fusee. A is the bottom of the fusee cone, which is hollowed out to receive the ratchet wheel, shown in position. This ratchet wheel and the fusee arbor are formed in one piece in three-quarter plate watches, and are fixed to the cone with three screws, the heads of which are sunk in the wheel; the arbor goes right through the cone and terminates in the winding square (shown at F); the ratchet wheel is nearly flush with the outer edge of the fusee brass. B is a thin steel wheel with clicks and springs projecting from its surface that act into the teeth of the ratchet wheel A. The use of these clicks is to permit the fusee to turn one way when the chain is wound on to it, and to prevent it from turning the other way without the steel and great wheels when the chain pulls it in that direction; the ratchet teeth of this wheel are cut in the contrary direction to those on the wheel at A. D and E are back and front views of the great wheel; E shows the maintaining-power spring let into a groove in the wheel, one end of which is fixed to the wheel by a pin going through, while the other end is free to move the distance of the slot; the pin in the free end of the spring projects, one end into the slot shown in D and E, and the other end into the hole in the ratchet wheel B, thus preventing these two wheels from moving more than the distance of the length of the slot independent of one another. Both the wheels are fitted to move freely on the fusee arbor, and are kept in their places by the collet shown at C, 1 and 2, in plan and elevation, which is fixed by a pin which passes through its pipe and the fusee arbor. A click, called the fusee detent, pivoted into the frame of the watch, is kept in contact with the teeth of the wheel B, by a weak spring screwed to the pillar plate; when the force of the main-

spring (which must always be stronger than the maintaining-power spring) is exerted and draws the fusee in the direction of the barrel, it will carry the steel wheel and the end of the maintaining-power spring to the end of the slot in the great wheel; the great wheel cannot move, from its teeth

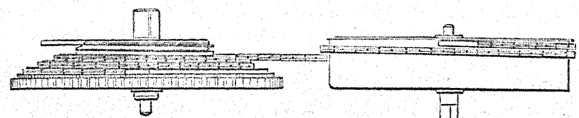


Fig. 3.—Fusee and Barrel with Chain attached.

engaging with the centre pinion, and the steel wheel is held where the mainspring has drawn it by the click or detent. If the power of the main-

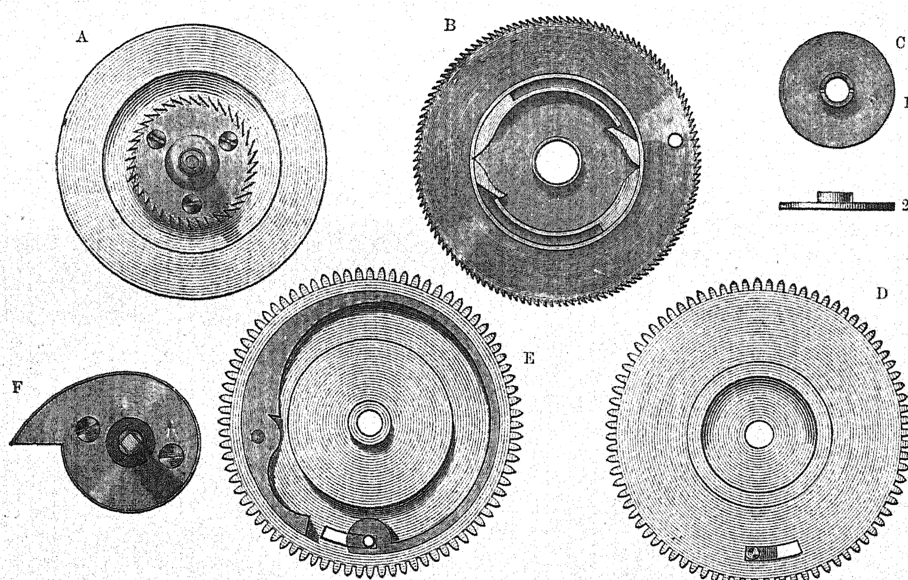


Fig. 4.—The Fusee.

spring is taken off by winding, the maintaining-power spring will exert sufficient force on the great wheel to keep the watch or chronometer going for a few minutes (more or less, according to the length of the slot in which the pin at the end of it acts). F is the upper end of the fusee, showing a steel cap fixed to the brass cone with two screws, the projecting hook of which stops the winding of the watch at the proper time, namely, when the chain is all wound round the fusee. The barrel arbor has a square cut on it, to which is fitted a small ratchet wheel on the dial side of the pillar plate, and a click (screwed to the plate fitting into the teeth of this wheel) prevents the arbor and wheel from turning when it is screwed down; this click and ratchet wheel are used only for setting the spring up sufficiently to get an adjustment of the mainspring; when the spring is adjusted, the click is screwed down, and the barrel arbor remains stationary.

The fusee (Figs. 3, 4) has four-and-a-quarter turns on it, which allows of the barrel turning three times on its arbor, and with a great wheel of 84 and a pinion of 12 the watch will go for thirty hours, giving six hours' grace in the case of irregular winding. The large end of the fusee should have a diameter double that of the smaller, and the cone should be slightly concave. There are some very complicated formulæ for calculating the proper shape of the fusee, but as the form must necessarily alter with the number of turns of the spiral cut upon it, and as the mainspring may be more or less taper, no rule can be stated for this that would serve any useful purpose; a fusee of the form given will, however, be adjustable. The larger end of the fusee and the barrel should be of the same diameter as the rim of the great wheel, the teeth projecting from the fusee about as much as does the chain from the barrel, and both should be as large as possible, as the larger they are in diameter the greater will be the power in proportion to the size of the watch.

PHOTOGRAPHY.—II.

By T. C. Hepworth, F.C.S.

[*Continued from p.* 36.]

HAND CAMERAS.

The ordinary form of quarter-plate camera has of late years been superseded to a great extent by the instrument known as a hand or detective camera. The latter title is misleading and ridiculous, for the detective camera is seldom able to detect anything. The hand camera is a very useful instrument, because pictures are often obtained with it the opportunity for taking which would be lost if it were necessary to erect an ordinary camera on its tripod stand. A case in point happened to the writer a short time ago when boating in the Irish Sea. He had with him an ordinary camera and stand, with which he had been taking some rock studies, when quite unexpectedly a whale came to the surface of the water and, before the camera could be brought to bear upon it, had disappeared. With the hand camera a portrait of the animal, which possibly would have been unique, could easily have been taken.

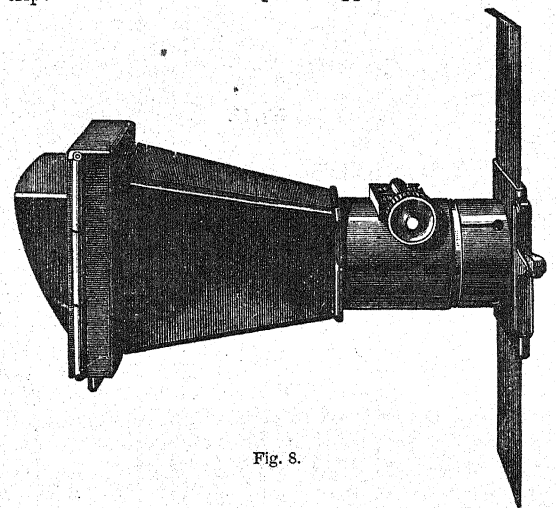


Fig. 8.

There are so many hand cameras now made, and so much ingenuity has been displayed in their construction, that it is quite impossible to pick out one in particular and allege that it is better than the others. All have their good points, and while some are too complicated by over-elaboration of details, others consist of little more than an ordinary camera enclosed in a box. As in most other mechanical contrivances, the more simple the design the more effective is a hand camera likely to be. We will now point out the leading features which, in our opinion, a hand camera should possess.

It should be unobtrusive in appearance. This is not the case with most of the hand cameras now sold, which are so singularly alike in outward appearance that no one is deceived as to their real nature. The operator himself can often by a little ingenuity obviate this by wrapping up the instrument in brown paper so as to look like an innocent parcel. This is necessary sometimes in crowded streets when one wishes to avoid observation. A ground-glass screen is unnecessary, unless the same camera be used on a tripod occasionally for ordinary work. A *Finder* is not a necessity, and with a little practice the operator will be able to point the instrument with precision and to secure horizontal lines, although he may fail in both respects at first. The shutter should be of simple form and need have only one speed. The focussing arrangement should be simple in character; indeed it is a question whether focussing be needed at all in these cameras. The writer has done excellent work with a hand camera with what is known as a fixed focus—the only inconvenience in its use being that near objects, say those within less than five yards, are blurred. In practice this does not often present any disadvantage. We will now briefly describe a few of the principal hand cameras which have been brought forward within the last few years.

The hand camera in its simplest form is shown at Fig. 8, which represents Marion's metal miniature camera. The little instrument is constructed wholly of aluminium, in order to secure lightness. It is furnished with a ground-glass screen for accurate focussing, and the dozen little single backs, also of metal—each containing a small dry plate—can easily be carried in the pocket. In front of the lens there is a simple drop shutter which falls, and exposes the plate on the touch of a trigger.

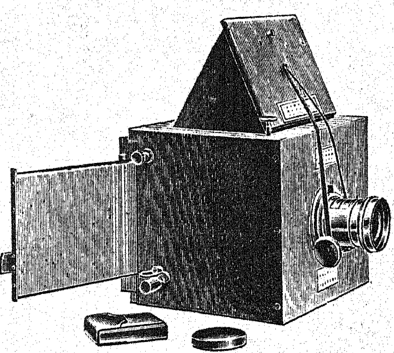


Fig. 9.

The little instrument is self-contained and thoroughly efficient. The camera is made in various sizes, from one taking plates $1\frac{1}{4} \times 1\frac{1}{4}$ square to the ordinary half-plate ($6\frac{1}{2} \times 4\frac{3}{4}$) size.

Loman's camera (Fig. 9) is of foreign origin, and it differs from most instruments in having a ground-glass screen at the top enclosed by a hood as shown. Within the camera is a sloping mirror which throws the image formed by the lens on to this screen. By this device the photographer can see the picture up to the moment when he touches the exposing trigger, when the mirror is turned aside and the image is thrown on to the sensitive plate behind it. This arrangement presents a great advantage in photographing moving objects, for such objects can be carefully watched until they are in the best position to make a satisfactory picture. At that moment their image is secured.

The two cameras just described employ dark slides for holding the sensitive plates, and in this respect they do not differ from cameras in general. But a number of hand cameras dispense with the dark slide altogether, and comprise a magazine of plates, containing a dozen or more, which by certain movements are brought one by one to focussing distance to be impressed by the light. The methods by which plates are thus changed are extremely diverse, and many of them are characterised by great ingenuity.

In Marion's "Radial Camera," for instance (Fig. 10), the plates are stored at the back of the instrument

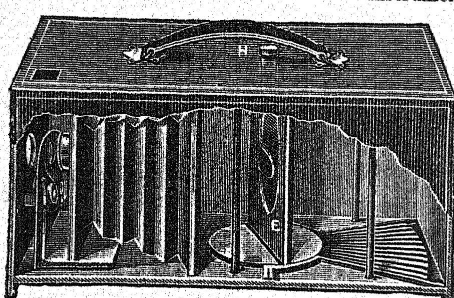


Fig. 10.

in grooves which radiate from one centre, hence the name of the instrument. These grooves are readily discernible in the annexed cut, and it will be noticed that the central point from which they radiate is found in a turntable in front of them. It will now be seen that each plate consecutively can be urged on to this table, when a half-turn will make it face the lens ready for exposure. After having been impressed by the light, it is once more turned round and restored to the particular groove from which it was taken. A useful feature of this camera is found in the fact that the plates can be stored in it just as they come out of their original boxes. In other forms of hand cameras—indeed in the great majority—each plate is fitted to a special metal sheath, or envelope, before it can be adapted to the instrument. In the next two cameras under review this system is exemplified.

Houghton's "Shuttle Camera" (Fig. 11), so named

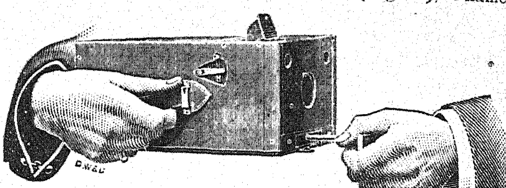


Fig. 11.

because each plate makes a to and fro movement, is a marvel of ingenuity, and it will be seen from the annexed cut—which is taken from a photograph—that it is small in size although taking quarter-plate pictures. The plates are changed and the shutter set by one simple operation, which consists in pulling out and returning a rod. One hand, in the illustration, is seen grasping this rod, which has a handle just below the lens. Within the camera this rod clutches hold of two projections on the metal sheath in which each plate is contained, and as it is drawn out it pulls sheath and all from the very back of the magazine, and rears it up in front ready for exposure. It is next to impossible to clearly describe the clever mechanism by which this is done—but the action is as sure as it is efficient.

Another good method of changing plates is exemplified in Fallowfield's "Facile Camera"

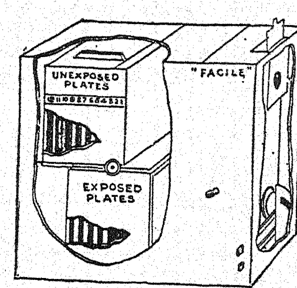


Fig. 12.

(Fig. 12). The illustration shows that the unexposed plates are contained in a grooved reservoir above the camera proper. This upper reservoir

moves upon the lower one by rackwork adjustment, and each plate drops down in turn ready for exposure.

This section of our work would certainly be incomplete without notice of the Eastman Company's "Kodak Camera" (Fig. 13). The word

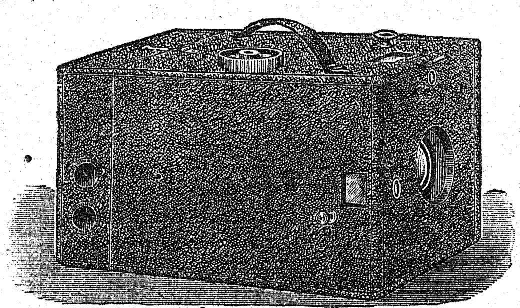


Fig. 13.

"Kodak" has no derivation, and has simply been adopted as a hieroglyphic which shall be different from any other word. The camera follows suit, for in design it is unique. Here, instead of plates, a rollable film is employed. This film is

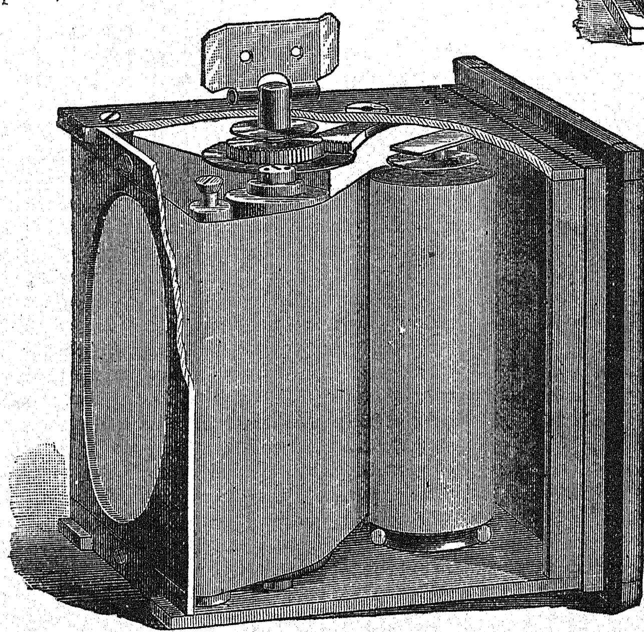


Fig. 14.

made of very thin transparent celluloid, which has received a coating of gelatino-bromide of silver. The Kodak is so arranged that this celluloid film in a long ribbon is fed between two rollers, successive portions being reeled out for different exposures.

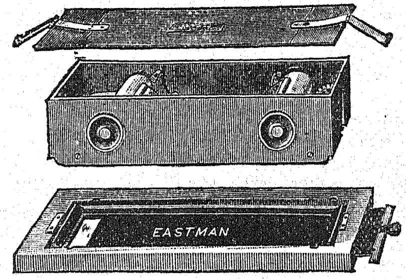


Fig. 15.

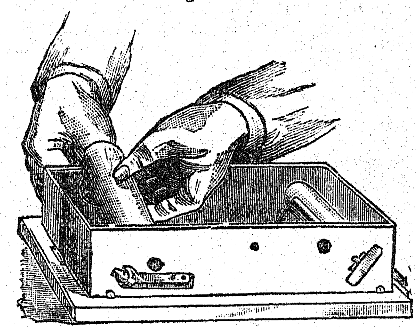


Fig. 16.

When the film is subsequently developed, it is cut into lengths each containing one, two, or three pictures as may be found most convenient. In Fig. 14 the whole inside arrangement of the Kodak is well shown, together with the winding key, which extends outside the camera, by which the rollers are actuated.

The rolling film principle is by no means confined to the Kodak hand camera, but had been adapted to cameras of all sorts and sizes long before the Kodak was introduced. For ordinary cameras this is brought about by the employment of a roll-holder, which fits on the back of the camera like an ordinary dark back, but which contains sufficient film for perhaps fifty exposures or more. Two cuts which show the various parts of the roll-holder, and the method of inserting the spools or reels, are seen at Figs. 15 and 16.

To the tourist using a large-sized camera the

roll-holder system is of special benefit, for the saving in weight, as against the use of glass plates, is enormous. The pictures produced on the celluloid film are in every respect equal to those obtainable with glass plates, with the extra merits of non-liability to breakage, and ease of transport and storage.

There are many pocket cameras obtainable for taking very small pictures. One is a watch camera, while another takes the form of an opera glass. Small cameras have also been adapted to hats, purses, and other personal belongings.

ELECTRICAL ENGINEERING.—II.

By Edward A. O'Keeffe, B.E.,
Senior Demonstrator in Electrical Engineering, City and Guilds of London Technical College, Finsbury.

[*Continued from p. 32.*]

INTRODUCTION (*continued*).

The motor is a machine peculiarly adapted for facilitating the distribution of energy. Where a small amount of power is wanted at some distance from the generating source, electricity appears to be the most convenient and most economical agent by means of which the necessary transfer of energy can be accomplished. Where a large natural supply of energy already exists—as, for instance, in the case of a waterfall—the motor may often be used with great advantage to do useful work at a considerable distance from the fall. The current which supplies the motor is conveyed to it through copper wires from a dynamo situated at the fall, the dynamo itself being driven by turbines or a water-wheel.

The dynamo is of later origin than the motor, and depends on the converse principle to that which governs the latter. This great discovery was made by Faraday in 1831. Œrsted had discovered that a wire, or coil of wire, carrying a current, acted upon a pivoted magnetic needle placed in its vicinity, and forced it to take up a position at an angle to the magnetic meridian, and forced it to retain this position as long as the current lasted. It occurred to Faraday that the converse might also be true—*i.e.*, if a magnet be placed in, or in the vicinity of, a coil of wire, a current might be generated in that wire. He took a coil of wire, and connected its ends to the terminals of a galvanometer which would show the presence of a current if any existed in the wire. He then placed a magnet in the coil, but found that no current was generated; and the same result was obtained however strong the magnet was, or however sensitive the galvanometer. While making this experiment, he noticed that at the moment when he placed the magnet in the coil the galvanometer gave a momentary deflection to one side and immediately returned to zero, and that when he withdrew the magnet it gave a similar deflection to the opposite side. These deflections could only be due to currents in the coil, and these currents were evidently only momentary. On further investigation he found that these currents lasted only as long as the motion of the magnet lasted; when that motion ceased the current ceased. The strength of the current depended upon the strength of the magnet, and the speed with which it was moved; while its direction depended upon the kind of pole which was moved, and the direction in which that movement took place. These currents are known as *induction currents*, and Faraday also discovered another and most important method by which they could be generated—namely, by the action of an independent current. He wound two coils of wire side by side on a wooden cylinder, connecting the ends of one coil to the terminals of a galvanometer, and the ends of the other to the poles of a Voltaic battery. The result which he obtained was somewhat similar to that just described. No matter what strength of current was sent through the one coil, the galvanometer showed that no current was passing through the other; but at the moments when the current started, and when it ceased, the galvanometer showed that momentary currents were generated, which were equal in strength, but opposite in direction. The coil in which the permanent current from the battery flows is known as the *primary coil*, the other as the *secondary coil.* He also found that any change in the strength of the current in the primary coil produced a momentary current in the secondary; and carrying his investigations a little farther, he found that if he took two coils of wire, in one of which a permanent current was flowing, and moved them near each other, a current was generated in the secondary coil, *which lasted as long as the relative motion of the two coils lasted.* When motion ceased, the induced current ceased also. The coil in which the permanent current was flowing behaved in every respect as if it were an ordinary magnet.

There appears to have been some doubt expressed at that time as to whether the effects above described were due to electricity, and perhaps it would be as well to close our account of his work on this subject with Faraday's own words:—"The various experiments of this section prove, I think, most completely, the production of electricity from ordinary magnetism. That its intensity should be very feeble and quantity small cannot be considered wonderful when it is remembered that, like thermo-electricity, it is evolved entirely within

the substance of metals retaining all their conducting power. But an agent which is conducted along metallic wires in the manner described, which, whilst so passing, possesses the peculiar magnetic actions and force of a current of electricity, which can agitate and convulse the limbs of a frog, and which, finally, can produce a spark through charcoal, can only be electricity."

This discovery of Faraday's revealed a new method by which currents could be generated. In 1833 Pixii constructed a machine in which a bobbin of wire was rapidly rotated near the poles of a powerful steel magnet, which induced currents in the coil. This bobbin has received the name of the *armature*, and this type of generator is known as the *magneto-electric machine.* These currents differed in two important points from those supplied either by Voltaic cells or thermo-electric generators; the cells and generators supplied fairly constant and *continuous* currents, whilst those supplied by the machine of Pixii were anything but constant, and what is of far more importance, they were *alternating—i.e.*, the direction of the current was regularly reversed as the coil was spun round. The first of these difficulties has since been overcome by winding the armature so as to be made up of a large number of turns of wire, in separate sections. The difficulty of the alternating currents has also been solved by fixing on the axis of the armature an arrangement called a *commutator*, which forces all the currents generated in the armature to flow in the same direction in the external circuit. Most of those little instruments sold as medical machines for giving "shocks," are Pixii machines constructed in a convenient form.

Larger machines of this class were built, but the currents which they generated were small when compared with the cost of the apparatus and its bulk. The next important advance in dynamo machinery was made by Wilde, who substituted powerful electro-magnets for the permanent steel ones which had previously been used. The current to excite these electro-magnets was supplied by an independent magneto-electric machine, and very powerful currents were generated by this means.

In 1867 both Siemens and Wheatstone suggested that these electro-magnets might be excited by the current generated in the machine itself, thus dispensing with the auxiliary magneto-electric machine used by Wilde; and this type, together with the many modifications which have since been introduced into it, is known as the *dynamo-electric machine.* Since that date the dynamo machine has developed so rapidly that at the present time it has arrived at such a stage that it is not only thoroughly reliable, but highly efficient.

All these continuous current dynamos are *reversible*—that is to say, they can be used as motors if supplied by an independent current.

The dynamo, in conjunction with the motor, is capable of doing a considerable amount of work at practically any distance from the central station where the power is supplied, and is capable of doing it in a fairly economical manner. It is not surprising then that many men have attacked the problem of how to drive trains and tramway carriages by its means. In the case of a train it was necessary to have a powerful motor placed in the engine and attached to the driving-wheel. When the current was allowed to pass through this motor, it expended its energy in doing the work necessary to drive the train. This current is generated by a dynamo machine situated at some convenient position along the line, and is carried to the motor either along the rails—in which case they must be insulated—or it must be carried along an independent insulated conductor, and communicated to the motor by a metallic brush attached to the engine and sliding along this conductor as the train moves. In the case of tram-cars the motor is also used, but it has been found advisable to supply the current in a different manner. *Accumulators* or *secondary batteries*, carried in the tram itself, are found more convenient for this purpose, these accumulators being charged at the terminus by a dynamo machine. The necessity for using insulated conductors in the public streets is thus obviated.

Many attempts have been made during the present century to store up electrical energy so as to render it available at some subsequent time; and though several men partially succeeded, Gaston Planté was the first to solve the problem in anything like a commercial manner. His accumulator consists of two sheets of lead wound in the form of a spiral, but without touching each other, and immersed in dilute sulphuric acid. When a current is passed through this cell, a film of dioxide of lead is formed on one of the plates, while the surface of the other is reduced to the state of spongy lead. While in this condition the cell is capable of giving a very powerful current for a length of time depending upon the state of the plates, and if the cell be in good condition it will retain its charge for a considerable time. In 1881 Faure, Sellon, and Volckmar introduced improvements in the Planté accumulator, which, with those which it has since undergone, render it invaluable in electrical engineering. No isolated installation of incandescent lamps is complete without a set of accumulators; in fact, they play that part in an electric light installation which the

gasometer plays in the common system of lighting by gas.

The transmission of sound by means of electricity involves principles which must be dealt with in detail. The *telephone* is extensively used in most large towns for transmitting speech, but the subject of long-distance telephony must still be looked upon as in its infancy, while at the same time it may be expected to spring to maturity with rapid strides.

Recent years have seen mighty changes wrought by electricity, which so readily assumes that form of energy which is most useful, while the continually increasing number of purposes to which it is being put to some extent foreshadows the importance of the position which it must necessarily hold in the immediate future.

THE DYNAMO.

ELEMENTARY PRINCIPLES.

Ever since Faraday's great discovery of the principle of electro-magnetic induction in 1831, inventors have been actively engaged in constructing machines capable of converting the energy of mechanical motion into that of electric currents. These machines—known as dynamos—have now been brought to that state of perfection beyond which any great improvement in principle is not likely to take place. When any machine has attained an efficiency of over 90 per cent., as is the case with the modern dynamo, there is but little room left for further improvement, excepting in the direction of mechanical details and in the adapting of the machine to special kinds of work. The principles of construction of the dynamo are now so well understood that there is little to choose between the different types of machines made by the leading manufacturers.

The goodness of a machine depends less upon its maximum efficiency than upon its adaptability to the purposes for which it is employed; for instance, a Brush machine may possess a fair efficiency when employed for running a number of arc-lamps, and yet be almost worthless for generating the currents required for electro-plating. A machine is designed to give a maximum efficiency under specified conditions of current and E.M.F., and if these conditions be varied the efficiency will fall off, though the machine may still be able to do the work required of it under the altered circumstances.

If a wire through which a current is flowing be wound into the form of a spiral, as shown in Fig. 1, it will act in every respect as if it were a magnet. Such an arrangement is called a *solenoid*. If the current enters through the wire at the point C, and leaves it at D, as is indicated at the arrowheads, the end marked B will be the north pole of the magnet, and A the south pole, whilst its strength will be proportional to the strength of the current in the wire. If the current flows in the

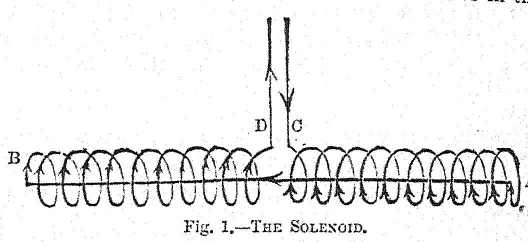


Fig. 1.—The Solenoid.

opposite direction through the wire, the polarity of the solenoid will be reversed. The similarity between the properties of the solenoid and the magnet led to the *Ampèrian theory of magnetism*, which was capable of explaining all existing phenomena. According to this theory a magnet is merely a substance round the surface of which a current is permanently circulating in a definite direction. Fig. 2 illustrates this conception of Ampère. The magnet has drawn on it the direction in which a current should circulate through a solenoid in order to have the same polarity as the magnet. Looking at the end, S, of the magnet, it will be seen that the current circulates in the direction of the hands of a clock, and this end is

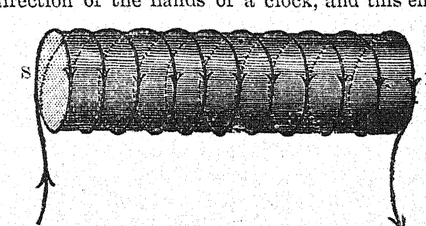


Fig. 2.—Ampère's Notion of a Magnet.

the *south pole*; looking at the north pole of a magnet, N, the current flows in the opposite—that is to say, in a counter-clockwise—direction.

It is well known that either two north poles or two south poles tend to repel each other, whilst a north and a south attract each other. It is also well known that two conductors through which currents are flowing tend to attract or repel each other, according to the directions in which the currents flow; if the currents flow in the same direction, a force of attraction is set up between the conductors; whilst repulsion takes place if the currents flow in opposite directions. The phenomenon of attraction between two opposite poles is a natural consequence of the attraction of two currents flowing in the same direction—according to the Ampèrian theory. Fig. 3 shows two magnets,

between which a force of attraction is exerted, their opposite poles being in proximity. It will be noticed that the currents are flowing in the same

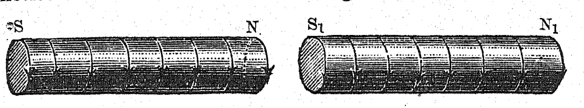


Fig. 3.—ATTRACTIVE ACTION OF TWO MAGNETS.

direction in the adjacent poles of the magnets, and a force of attraction must therefore exist between them.

Fig. 4 shows two magnets, their north poles, N and N_1, being in proximity, and a force of repulsion is exerted between them; it will be seen in this case that the Ampèrian currents circulate in opposite directions in the adjacent poles, and that repulsion must therefore take place between them.

In order to move either magnet against either of these forces, a definite amount of energy, depending upon the strength of the magnets, must be expended. If a coil of wire, forming a closed circuit, is placed in the vicinity of a magnet and

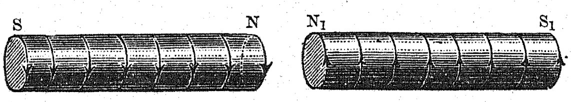


Fig. 4.—REPELLENT ACTION OF TWO MAGNETS.

then suddenly withdrawn, a certain amount of energy must be expended, over and above that which would be necessary to make the same movement if the magnet were not present. The explanation of this phenomenon is that the motion of the coil sets up a current in it, which converts it into a temporary solenoid. This current flows in such a direction as to exert a force of attraction between the magnet and coil, and work must therefore be done in overcoming this force over the distance moved. If, on the other hand, the coil had been moved at the same speed from a distance up to the magnet, an equal amount of energy would have been expended; in this case the current generated in the coil by its motion towards the magnet would have been in the opposite direction to the previous one, and would therefore have given rise to a force of repulsion between the coil and magnet. If the poles of the magnet be reversed, the directions of the currents induced by it in the coil will be reversed. The direction of the induced current may always be known by remembering that the direction of the Ampèrian current round the south pole of a magnet is in a clockwise direction, and round the north pole in a counter-clockwise direction, and that *by Lenz's law the induced current in the coil will always be in such a direction as will tend to oppose the motion.*

In considering the action of a dynamo, it is best to look upon a magnet in the same way as Faraday did — that is, as a substance through which imaginary *lines of force* are passing; these lines enter at the south pole and come out at the north, whilst the strength of the magnet is proportional to the number of these lines passing through it. If the space about the poles of an ordinary horse-shoe magnet be examined, it will be found to be full of these lines, which form symmetrical curves between the two poles. Fig. 5 shows these curved lines passing between the poles marked N and S, which are the ends of a horse-shoe magnet. This diagram is obtained by resting a stiff card horizontally on the ends of the magnet, and sprinkling iron filings over it. The filings, on falling on the card, immediately set themselves along lines of force, and the effect may usually be improved by gently tapping the card. If a small compass be brought into this space, it will immediately set itself with its axis tangential to a line of force. These diagrams are often extremely useful in examining the nature of the *field* (as the magnetic region is called) about the armature of a dynamo; and where it is desirable to preserve them, the following device may be adopted. Instead of using a stiff card, take a sheet of blotting-paper which has been soaked in melted paraffin wax, and, having placed it horizontally in that portion of the field which it is desired to examine, sprinkle the filings, and tap gently till they have settled into a definite diagram; now bring the flame of a spirit-lamp under the

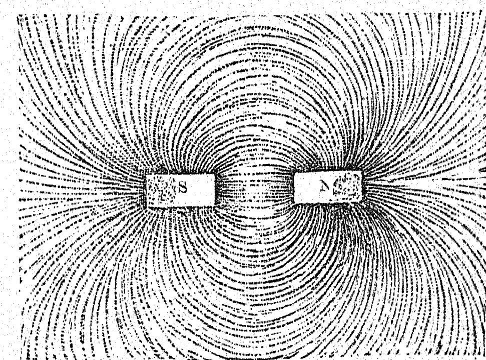


Fig. 5.—LINES OF FORCE BETWEEN THE POLES OF A MAGNET.

different parts of the paper, so as to soften the wax with which it is soaked. The filings sink into the softened wax, and as this becomes hard almost as

soon as the flame has been withdrawn, a permanent diagram of that portion of the field is easily and quickly obtained. In Fig. 5 it will be noticed that the lines passing immediately between the poles are almost straight, and that as we recede from that portion of the field the lines become curved and gradually get fewer in number. The strength of the field at any place is measured by the number of lines of force passing through unit area at that place; in this diagram it will be seen that the strength is greatest in the space immediately between the poles, and falls off as we recede from that position.

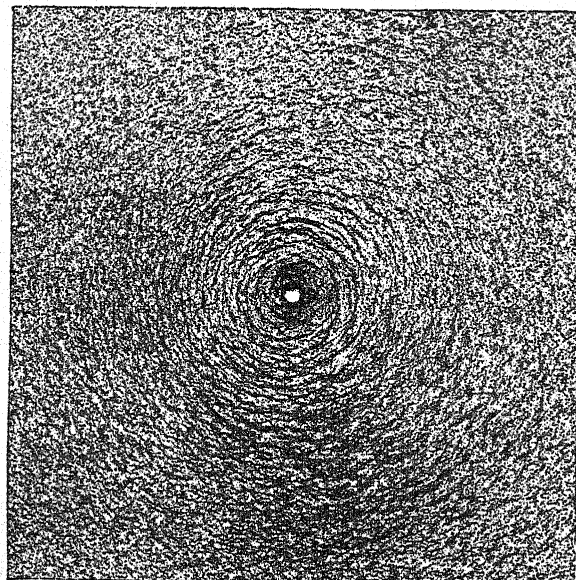


Fig. 6.—Magnetic Whirls round a Wire carrying a Current.

As the modern theory of dynamo design is entirely founded on our accurate knowledge as to the number of lines of force passing through given substances, it is as well to start with definite ideas on the subject; and in order to do so, it becomes necessary to introduce two definitions, one for the strength of the magnetic field, and one for the strength of the magnetic pole. *A magnetic field is said to be of unit strength when the number of lines of force passing across it at right angles to its section is at the rate of one line per square centimetre*, or 6·45 *lines per square inch*. This is an extremely feeble field when we consider that strengths as great as sixteen and seventeen thousand lines per square centimetre are commonly employed in modern dynamos.

The second definition is that of unit magnetic pole, which is defined as *one which at a distance of one centimetre in air from a similar pole repels it with a force of one dyne*. A magnetic field of unit strength exists all round a magnetic pole of unit strength at a distance of one centimetre from it, and hence we have a means of determining the number of lines of force passing through the magnetic pole. The number clearly is the same as the number of square centimetres on the surface of a sphere of one centimetre radius surrounding the pole, since this number allows one line per square centimetre—or, in other words, unit field—all round the pole at a distance of one centimetre from it. Now, the number of square centimetres on a sphere of one centimetre radius is 4π, and hence there must be

$$4\pi$$

lines of force passing through a magnetic pole of unit strength; and for a magnet having a strength of m, there must be $4\pi m$ lines passing through it.

Whatever may be the nature of an electric current, we know that it exerts magnetic effects in the medium surrounding it. If a current passes through a straight wire, it sets up magnetic whirls round that wire; in other words, it generates and maintains lines of force in the space surrounding it. These lines form concentric circles round the wire, and get wider apart as the radii of the circles increase. The generation of these lines necessitates the expenditure of a certain amount of energy when the current is started, and it is this fact which prevents the current from rising to its full strength when the circuit is completed. The distance to which this magnetic disturbance may extend from the wire is often considerable, as many people well know who are obliged to use the telephone in districts where heavy mains are laid. It is sometimes impossible to hold any intelligible conversation on a telephone line owing to the disturbing magnetic effects exercised by the currents flowing in neighbouring conductors, especially when those currents are intermittent or alternating.

In Fig. 6 this state of things is well shown. The figure was obtained by passing a current of 45 ampères through a vertical wire, and sprinkling fine iron filings from a pepper canister on a horizontal piece of paper—prepared as above described—through which the wire passed. A similar diagram can be obtained with a much weaker current, but where strong currents are available the effects are more strikingly exhibited.

THE STEAM ENGINE.—II.

By ARCHIBALD SHARP, B.Sc., WH. Sc., A.M.I.C.E.
Instructor in Engineering Design at the Central Institution of the City and Guilds of London Institute.

[*Continued from p.* 44.]

MEASUREMENT OF HEAT—TEMPERATURE—THERMOMETERS.

EVERYONE is familiar with the sensations experienced on touching a hot body or a cold body. A hot body is said to have a higher temperature than a colder body. A thin iron wire heated to redness has a higher temperature than a basinful of lukewarm water. Two bodies have the same temperature if, when placed in contact with each other, there is no communication of heat from the one to the other. If two bodies having different temperatures be in contact, heat will flow from the hotter to the colder body, and the temperatures of the bodies will become more and more nearly equal. Note carefully that temperature is not heat, nor do degrees of temperature always indicate quantities of heat, but temperature is a property, a quality, of heat. The basinful of lukewarm water referred to above, although having a much lower temperature than the piece of red-hot iron wire, will probably possess a far greater quantity of heat.

Nearly all bodies when heated expand in volume and contract again when cooled. This property is used practically for estimating the temperature of any body. An arbitrary scale of temperature might be defined as follows. A solid rod may be taken whose length at the lowest temperature to be measured is l, its length at any other temperature will be $l + x$, where x is the increase of length due to the heating of the rod. If the temperature of the rod when its length is l be taken as zero, the degrees of temperature corresponding to length $l + x$ is proportional to x. It is evident that a scale of temperature like this depends not only on the heat supplied to the rod, but also on the physical properties of the material from which it is made.

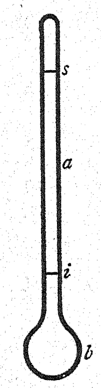


Fig. 20.

Mercurial thermometers, which are oftenest used, are made in the following manner. A glass tube a, the bore of which is uniform throughout, has a bulb b (Fig. 20) blown at one end. The bulb and tube are filled with mercury, taking care that all the air is expelled. The mercury is heated, and while hot the open end is hermetically sealed. On cooling, the mercury is found to have left the upper part of the tube. The bulb is immersed in a mixture of ice and water and a mark made on the tube at the level of the top of the mercury i. The temperature of melting ice is invariable, so the mark i corresponds to a known fixed temperature. A mark s is made corresponding to the temperature of boiling water when the height of the barometer is 29·9 inches of mercury. The distance is may now be divided into a number of equal parts and the divisions numbered, the space below i and above s may also be marked off with the same divisions; the degrees of temperature of a body will be given by the number of the division at which the top of the mercury stands when it has the same temperature as the body.

There are two thermometric scales in general use. In the Centigrade scale the temperatures of melting ice and boiling water are 0° and 100° respectively. In the Fahrenheit scale these temperatures are 32° and 212° respectively. The zero of the Fahrenheit scale—32° Fahrenheit below the melting-point of ice—was the lowest temperature known at the date of the invention of the scale, and was supposed to represent the temperature of a body absolutely devoid of heat. However, since then much lower temperatures have been observed.

To convert degrees Fahrenheit into degrees Centigrade, or *vice versâ*, the two following formulæ are used—

$$C.° = \frac{5}{9} F.° - 32$$

$$F.° = \frac{9}{5} C.° + 32$$

The air thermometer is made from a capillary tube, open at one end and having a bulb blown on the other end. The bulb and capillary tube is filled with dry air and heated, a drop of strong sulphuric acid is introduced by the end of the tube and serves to divide the air in the thermometer from the atmosphere, and so forms the index of the thermometer. As the temperature falls, the drop of acid recedes up the tube; its position will depend on the temperature of the air in the bulb. The temperatures 32° F. and 212° F. are marked on the tube in the manner described for the mercurial thermometer. If the temperature of a body between 32° F. and 212° F. be measured by a delicate mercury thermometer and also by a delicate air thermometer, the two readings will in general differ by a small quantity. We will return to the discussion of this point later on.

MEASUREMENT OF QUANTITIES OF HEAT.

The quantity of heat necessary to raise the temperature of 1 lb. of water from 39° to 40° F. is called the British Thermal Unit.

It is found by experiment that the quantity of heat necessary to raise the temperature of 1 lb. of water 1° F. varies slightly with the initial temperature of the water. Hence the necessity

of defining the thermal unit as the quantity of heat necessary to raise the 1 lb. of water from a definite temperature to a temperature one degree higher. Water is at its maximum density at 39·1° F., that is, at this temperature it has less bulk than at any other temperature.

SPECIFIC HEAT.

If equal weights of different substances are exposed to the same heating agency for the same length of time, it will be found that the temperatures will be quite different. In other words the quantity of heat necessary to raise the temperature 1° F. is different for different substances. The amount of heat measured in British thermal units necessary to raise the temperature of any substance 1° F. is called the specific heat of the substance.

The following table gives the specific heats of a few solids and liquids:—

Water at 39° F.	1·000
Ether	·720
Mercury	·033
Petroleum	·434
Ice	·504
Copper	·095
Iron	·114
Tin	·051
Zinc	·093

These are average values which are accurate enough for most purposes. It is found, however, that the specific heat of solids and liquids slightly differs at different temperatures. The specific heat of water between 32° F. and 250 F. does not differ very much from 1·00, but above 250° F. the excess of the specific heat above unity is so great as not to be negligible in accurate thermal calculations relating to steam engines.

We will return to the subject of specific heat of gases in a later lesson.

We are now in a position to express the quantitative relation between heat and work as follows: "Heat and work are mutually convertible, one British thermal unit being equivalent to 778 foot-pounds of work."

The number 778 is the mechanical equivalent of heat. The value of the mechanical equivalent of heat which has been in use for the last forty years is 772, and was determined by Joule from a series of experiments on the heat produced by the agitation of water by paddles. Joule also determined the mechanical equivalent of heat by experimenting on the heat produced by electric currents, the value obtained being 782. Later, in 1879, Rowland, at Baltimore, experimented with an apparatus similar to Joule's, but with several modifications, which make the results more trustworthy. The value of the mechanical equivalent obtained was 778. This value has been used by the most recent writers on thermodynamics of the steam engine—Peabody and Wood—and will be used in these lessons.

One horse-power is equivalent to the expenditure of $\frac{33000}{778} = 42·4$ thermal units per minute.

To find the mechanical equivalent of heat when the Centigrade scale of temperature is used, and 1 foot is the unit of length, multiply 778 by $\frac{9}{5}$. The result is 1,400. That is, 1,400 foot-pounds of work are required to raise the temperature of 1 lb. of water 1° C.

The mechanical equivalent of heat—metres, kilogrammes, and degrees Centigrade being the units used—will be

$$778 \times \frac{9}{5} \times 0·3048 = 427.$$

1° C. being equal to $\frac{9}{5}$° F., and 1 foot being equal to 0·3048 metre. No factor for converting pounds into kilogrammes is necessary, since in the definition of the mechanical equivalent of heat the weight of water heated is the same as the weight lifted through unit distance to give the unit of work.

GASES.

A gas is a body having the power of indefinite expansion, and differs in this respect from solids and liquids. If a small quantity of gas be introduced into a closed bottle, it will not collect at the bottom as a liquid would, but will expand and fill the bottle, and will only be limited as to volume by the pressure of the sides of the bottle. If the bottle be opened in a closed room the gas will expand still further, and ultimately will be diffused uniformly throughout the room.

When a gas is confined, it presses equally on all parts of the inner surface of the enclosing vessel. For a given quantity of gas it is found that the amount of pressure exerted on a square inch of surface is inversely proportional to the total volume occupied.

Boyle's Law.—Imagine a long cylinder 1 square inch in sectional area, closed at one end and open at the other, having a piston closely fitting, allowing no air to escape past it, and yet moving easily on the cylinder (Fig. 21). Let the piston be 1 inch from the bottom of the cylinder when there is no force applied to the end of the piston rod. The volume of air enclosed is 1 cubic inch, and its pressure on the face A A of the piston must be equal to the pressure of the atmosphere on the face B B, say, 15 lb. (14·7 lb. per square inch is the average

pressure of the atmosphere). If now the piston be pulled out until the face A A is 2″ from the bottom of the cylinder, the volume of the air is 2 cubic inches, and if the pull on the end of the rod can

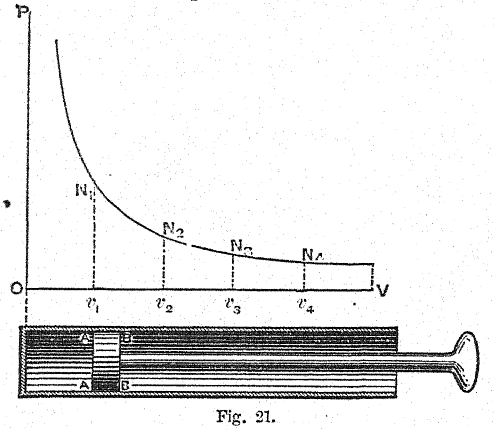


Fig. 21.

be measured it will be found to be 7·5 lb., provided the temperature of the air is the same as at the beginning of the experiment. This pull tends to make the piston move towards the right, and so does the pressure of the air on the face A A, while the pressure of the atmosphere on B B 15 lb. tends to make the piston move to the left. These forces balance each other, and therefore

Pressure on A A + 7·5 lb. = 15 lb.,

∴ pressure on A A = 7·5 lb.

That is, when the gas occupies twice the original volume the pressure it exerts on a unit of area of its containing vessel is half the original pressure.

In the same way, with the same condition as to the temperature of the air in the cylinder, if the volume be multiplied by 3, 4, or 5, the corresponding pressure will be divided by 3, 4, or 5.

The relation between the volume occupied and the pressure per unit area exerted by the gas can be exhibited graphically. In Fig. 21 draw O V and O P at right angles. Then the volume occupied by the gas at any time will be represented by a line O v and the corresponding pressure of the gas by $v\,p$ at right angles. The scales of volume and pressure may be taken as convenient. If this construction be repeated for a number of different volumes v_1, v_2, v_3, a curve may be drawn through the extremities N_1, N_2, N_3 of the corresponding ordinates.

Such a diagram will often be used to show the relation between two quantities which are mutually dependent. In the above diagram O v is called the abscissa and v N the ordinate of the point N on the curve.

The above relation is expressed by saying that the pressure of a gas varies inversely as the volume.

Algebraically.—If v denote the volume occupied by the air and p the corresponding volume $p \propto \frac{1}{v}$ or $p\,v =$ Constant . . . . (1).

The constant in the formula can be found by taking the product of two corresponding values of the pressure and volume; for example, in the case under consideration, when the volume is 1 cubic inch, the pressure is 15 lb. per square inch, and the constant of the formula will be 1×15, and the formula may be written $p\,v = 15$.

The above relation is approximately true for all gases. Note that the temperature of the gas is the same throughout.

Law of Charles, or *Gay Lussac's Law*.—If now the piston be subject to atmospheric pressure while the temperature of the air is gradually raised, it will be found that the volume of the air increases with the temperature. The increase of volume per degree rise of temperature is found to be $\frac{1}{492}$ part of the volume at 32°. The variation of volume with temperature while the pressure remains constant can therefore be represented by the equation

$$v = C\,(460 + t^\circ) \quad . \ . \ . \ . \ . \ . \ . \ (2),$$

t being the temperature measured on the Fahrenheit scale.

This statement is called the "law of Charles," or "Gay Lussac's law," after the first investigators of the subject.

If in equation (2) we substitute $T = 460 + t^\circ$, it becomes $v = c\,T$ . . . . (2a).

T is the temperature of the gas measured on a scale the degrees of which are equal to the degrees of Fahrenheit's scale but having its zero 460° lower than the zero of Fahrenheit's scale. T is called the "absolute" temperature, and $T = 0$ is the ideal temperature of a body absolutely deprived of heat.

EQUATION OF A PERFECT GAS.

Combining equations (1) and (2a) we may write

$$p\,v = R\,T \quad . \ . \ . \ . \ . \ . \ (3),$$

R being a constant. The quantity of gas taken is usually unit mass 1 lb., and then v is the volume occupied by 1 lb. of gas at the pressure p and temperature T, and is called the "specific volume." The constant R has for air the value 53·21; feet, pound, and degrees Fahrenheit being used.

A "perfect" gas is one in which the relation between pressure, volume, and temperature is *perfectly* represented by equation (3). For all practical purposes the so-called permanent gases—that is, gases which do not liquefy at ordinary

temperatures—may be regarded as perfect gases, though, strictly speaking, all gases are more or less imperfect.

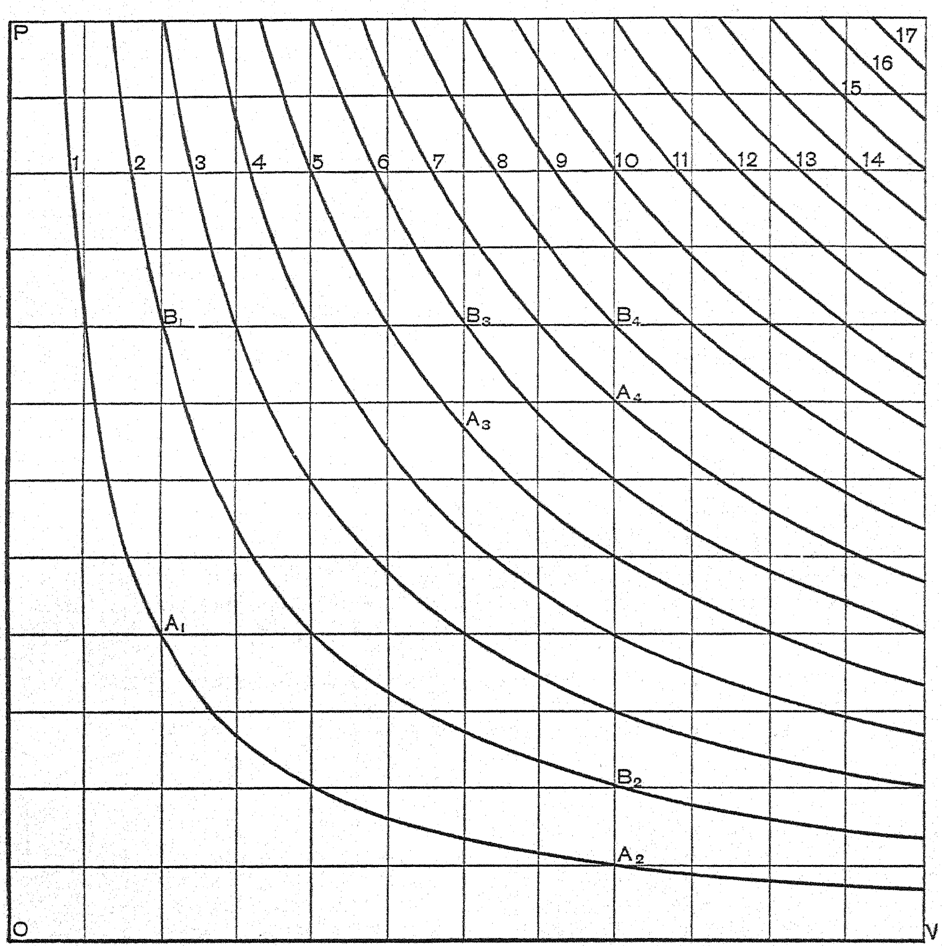


Fig. 22.

series of isothermal lines for air, the absolute temperatures being proportional to the numbers affixed to the curves. For perfect gases the isothermal lines are a series of equilateral hyperbolas having the axes O P and O V as asymptotes.

EXPANSION OF GASES—ISOTHERMAL EXPANSION.

We have already considered one case of expansion of a gas (page 107), namely, that in which the temperature of the gas remains the same during the expansion. Such an expansion is called isothermal, and the curve N_1 N_2 N_3 . . . . (Fig. 21) is called an isothermal line of the gas experimented on. If the temperature of the gas in the experiment described were 60°, then the curve is the isothermal corresponding to 60°. If the temperature be raised to 70° and the experiment repeated, another isothermal line will be got. In this way a series of isothermal lines may be drawn. Fig. 22 shows the series of isothermal lines for air, the absolute temperatures being proportional to the numbers affixed to the curves. For perfect gases the isothermal lines are a series of equilateral hyperbolas having the axes O P and O V as asymptotes.

It is found that heat must be given to the expanding gas to keep its temperature uniform, similarly if the gas be compressed, heat must be taken from it to keep its temperature constant.

It will be useful to give here a simple geometrical construction for drawing an equilateral hyperbola, having given the axes and one point on the curve.

Let O X and O Y (Fig. 23) be the given axes and P the given point on the curve. Through P draw parallels to O X and O Y. Through the origin O draw any line A B, cutting the parallels through P

in A and B. From A and B draw parallels to O X and O Y, completing the rectangle A P B C. C is a

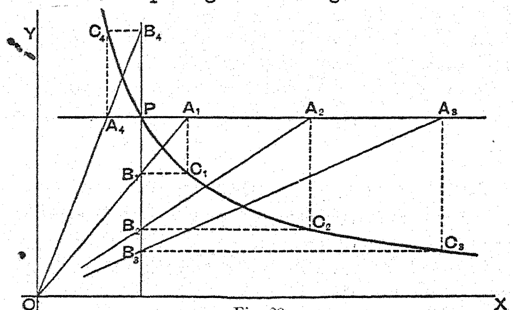


Fig. 23.

point on the curve. In Fig. 23 the construction has been made for four points, and a fair curve drawn through them.

DRAWING FOR ENGINEERS.—II.

[*Continued from p. 48.*]

PENCIL DRAWINGS (*continued*).

Example 3.—Draw the pattern shown in Fig. 12. This is an exercise on the accurate use of the 60° set square. A B may be taken as the base

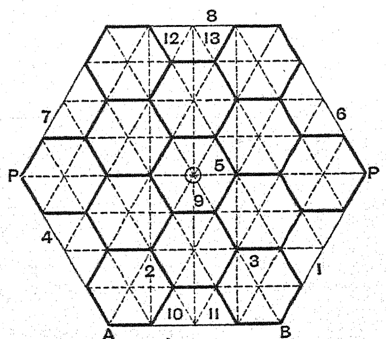


Fig. 12.

line 4″ long. The order of drawing the first few lines is indicated by the figures.

Example 4.—Draw the figure shown in Fig. 13. This is an exercise on the use of the compasses. The circular arcs must be joined to each other with no visible break in the lines.

Example 5.—Inscribe circles in the squares of Fig. 11, and in the hexagons of Fig. 12.

These examples afford practice in inking-in.

Example 6.—Draw a bolt 1″ diameter with hexagonal head and nut (Fig. 14). We will go carefully over the working out of this example, as it occurs so very frequently. The student is recommended to practise it until he can draw it fairly quickly. In fact, to cultivate speed in drawing, the student should do a great many of his drawings a second time; he will find that the time required for the

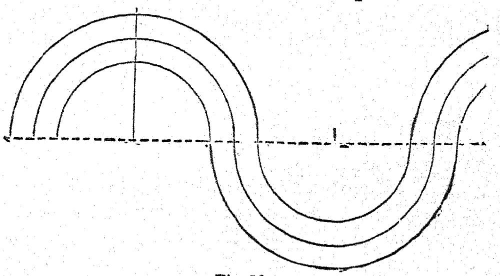


Fig. 13.

second drawing is in many cases not half that required for the first.

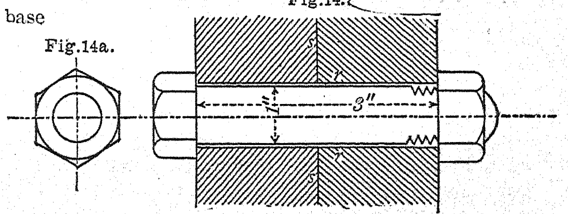
1. Draw the centre line $a\,a$ (Fig. 15) by aid of the T-square, firm. The centre lines are dotted in the woodcuts, but should be drawn continuous.

2. Set the edge of the scale along $a\,a$, and with the pencil mark off $b\,c = 3''$.

3. Draw the two lines $d\,d$ and $e\,e$ through b and c respectively, faint.

4. Mark off $bf = \frac{1}{2}''$ on each side of centre line.

Fig. 14a. Fig. 14.



5. Draw the lines $f\,g$ up to within $\frac{1}{8}''$ or $\frac{1}{4}''$ of $e\,e$, firm; and produce them to h, faint.

The depth of the nut is usually equal to the diameter of the screw, and the width of the nut across the corners is equal to twice the diameter of the screw, therefore—

6. Set off $c\,i$ along the centre line $= 1''$ and $c\,j$ on each side of the centre line $= 1''$.

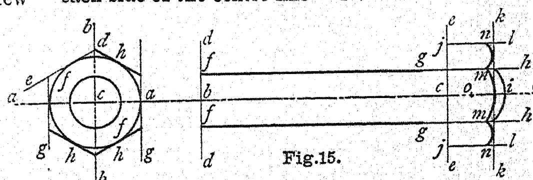


Fig. 15a.

7. Draw the lines $k\,k$, $j\,l$, through i and j respectively, faint.

The chamfer—that is, the bevelling of the top edge—on nuts is usually a little greater than that shown in Fig. 14, but for convenience of drawing it is usual to show it as in the figure. The chamfer

surface is usually part of a cone, and then the curves *m* and *n*, if drawn strictly accurate, would be arcs of hyperbolas. The student who has studied Practical Solid Geometry (*see* lessons on Projection) will be able to draw these hyperbolic arcs. But the draughtsman's conventional method is the following:—

8. With centre *c* draw the circular arc *m m* touching the line *k k*, firm.

9. Find by trial the centre of a circle which will pass through *m*, the point *n* on *j l* exactly opposite *m*, and which will touch the line *k k*; and draw the arc *m n*, firm.

A geometrical construction must *not* be used for this or for similar cases of drawing circles to satisfy certain conditions. With practice the student will be able to draw such circles by trial as accurately and more quickly than if he had used a geometrical construction.

10. With centre somewhere about *o*—its exact position is not important—draw the arc *p*, representing the end of the screw projecting a little through the nut, firm. The drawing will now have the appearance shown in Fig. 15.

11. Rub out the superfluous faint lines and firm

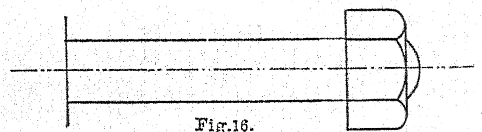


Fig.16.

in the remaining faint lines. The drawing has now the appearance shown in Fig. 16.

The correct projection of the screw threads would require more time than the draughtsman can afford. Fig. 18 shows a very good conventional method of representation. The pitch of a screw 1″ diameter is $\frac{1}{8}$″ so—

12. Mark off points *q q q* along *g m* $\frac{1}{8}$″ apart.

13. Through *q q* draw a series of lines inclined 60° to the centre line of the bolt, faint.

14. Reverse the set square, and draw another series inclined 60° in the opposite direction.

15. Rub out the superfluous lines and firm in the remaining faint lines.

16. The hexagonal bolt-head will be drawn in the same way as the nut, but its dimensions are less, say depth $\frac{7}{8}$″ and width across corners $1\frac{3}{4}$″.

17. The hole in which the bolt lies should be $\frac{1}{32}$″ to $\frac{1}{16}$″ larger than the body of the bolt. These lines *r r* can be drawn firm, and the line *s s* firm, midway between *d d* and *e e*.

Fig. 14 is a section showing the bolt and nut (in elevation) used to screw two flanges together.

18. Section lines inclined 45° are drawn over the parts cut by the plane of section.

The drawing of the longitudinal elevation of the bolt (Fig. 14) is now finished.

To draw the end elevation (Fig. 14*a*):—

1. Draw the centre lines *a a* and *b b* intersecting at *c* at right angles, firm. (*See* Fig. 15*a*.)

2. Set off from the edge of the scale *c d* equal to the diameter of the screw, *i.e.* 1″.

3. Through *d* draw *d e* inclined 60° to *b b*, faint.

4. With centre *c* draw a circle *f f* touching *d e*, firm; and draw another circle with same centre and 1″ diameter, firm.

5. With the set square draw the lines *g*, *g* parallel to *b b* and touching the circle *f*, faint.

6. Draw the lines *h*, *h*, *h* inclined 60° to *b b* touching the circle *f*, firm. The drawing will now have the appearance (Fig. 15*a*).

7. Rub out the superfluous lines and firm in the remaining faint lines.

When a number of nuts have to be drawn the circle *f* should be drawn first for each nut, and then the six sides of the hexagon can be drawn touching this circle. The hexagon must on no account be constructed by drawing the circumscribing circle, *i.e.*, the circle passing through its six angular points, as this construction is longer, and involves the drawing of a circle which must afterwards be rubbed out.

Sometimes it is necessary to make a longitudinal elevation showing two faces of the nut, as in Fig. 17.

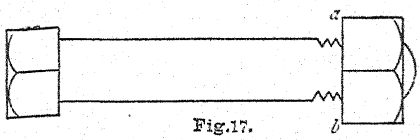


Fig.17.

Here the length *a b*—that is, the width of the nut across the flats—is equal to the diameter of the circle *f* (Fig. 15*a*).

Two additional conventional methods of representing screw threads are shown in Figs. 19 and 20.

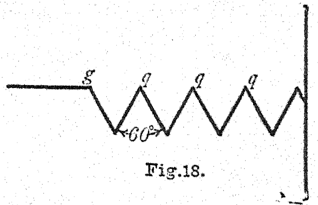


Fig.18.

In Great Britain a standard form of screw thread has been adopted by engineers for bolts and nuts. It is called, after its proposer, the Whitworth screw thread, and its section shown in Fig. 21. It is triangular in general appearance, the angle *b a c* being 55°. One-sixth part of the depth of the Vee *a d* is

rounded off at the top and bottom of the thread. The following table gives the principal dimensions of Whitworth triangular screw threads.

Diameter in inches.	Number of threads per inch.	Width of nut across flats.	Diameter at bottom of thread in inches.	Sectional area at bottom of thread. sq. ins.
$\frac{1}{4}''$	20	·525	·186	·027
$\frac{5}{16}''$	18	·601	·241	·046
$\frac{3}{8}''$	16	·709	·295	·068
$\frac{1}{2}''$	12	·919	·393	·121
$\frac{5}{8}''$	11	1·101	·509	·204
$\frac{3}{4}''$	10	1·301	·622	·304
$\frac{7}{8}''$	9	1·479	·733	·422
1″	8	1·670	·840	·554
$1\frac{1}{8}''$	7	1·860	·942	·697
$1\frac{1}{4}''$	7	2·048	1·067	·894
$1\frac{3}{8}''$	6	2·215	1·161	1·058
$1\frac{1}{2}''$	6	2·413	1·286	1·299

In America the standard screw thread (Sellers') has the angle of the thread 60°. The angles are cut off parallel to the axis of the bolt at a distance equal to an eighth part of the depth of the Vee (Fig. 22). One advantage of this thread over Whitworth's is

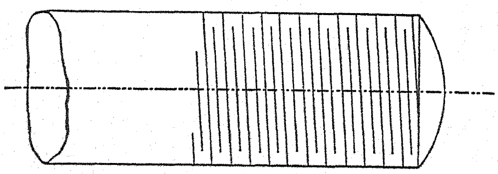


Fig.19.

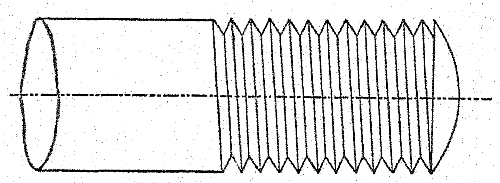


Fig.20.

that it can be cut in the lathe by one tool, and does not require to be finished with a comb, or chaser, as does a Whitworth screw.

Screw bolt and nut fastenings are largely employed in all kinds of machinery. The fastening depends ultimately on the friction between the nut and the screw. In quick-running machinery the rapid alternations of the direction of motion tend to loosen the nut, and special means must be taken to prevent the nut slackening. One of the commonest methods is to use two nuts, which are screwed hard against each other, and so "lock" each other on the bolt.

Example 7.—Fig. 23 shows a locking washer for nuts on large bolts, such as main bearing or connecting-rod end bolts of large engines. The washer W fits loosely round the hexagonal nut and is secured to the piece the principal nut holds by the two set-screws S. Two holes are tapped to receive these set-screws, and several pairs of holes are

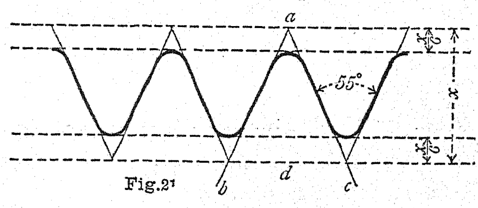


Fig.21

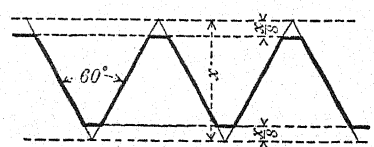


Fig.22.

drilled in the washer W. We will design the washer so that the nut may be secured in positions differing by a thirty-sixth part of a complete turn.

The width of the nut across the flats is 4·531″ and the width of the corresponding hexagon of the washer may be a little larger, say $4\frac{5}{8}''$. Draw the plan of it and project up the elevation of the nut. The set-screw may be $\frac{3}{4}''$ diameter, and its centre line should be drawn so as to allow its head to clear easily the edge of the nut. Through d, the plan of the centre of the set-screw, draw a circle, and let d Q be one-sixth of the circumference of the circle. Now if the nut be screwed up a sixth of a turn the washer will fit over it in exactly the same position as before. We have therefore to divide the arc d Q into six equal parts at 1, 2, 3, 4, 5. It is evident that if the washer be put over the nut with its under side up, and with the line O 3 in the same position, the points d, 1, 2, coincide with the former positions of points Q, 5, 4 respectively. Therefore, if three holes, with centres A, B, and C in the middle of d1, 1 2 and 2 3 respectively, be made large enough to let the screw B pass through, the problem is solved. Practically it is more convenient to make the holes B and C at another part of the washer but having the same relative position to one of the hexagonal sides. Set off, therefore, Q $B_1 = d$ B and R $C_1 = d$ C. A, B_1, and C_1 are the centres of the holes through the washer; they may be $\frac{7}{8}''$ diameter. To secure the washer better, the set-screw and the holes in the washer are duplicated, as shown in the figure. In the plan the nut is shown in such a position that the set-screws could not be fixed until the nut was slackened back slightly. If the holes in the washer be elongated

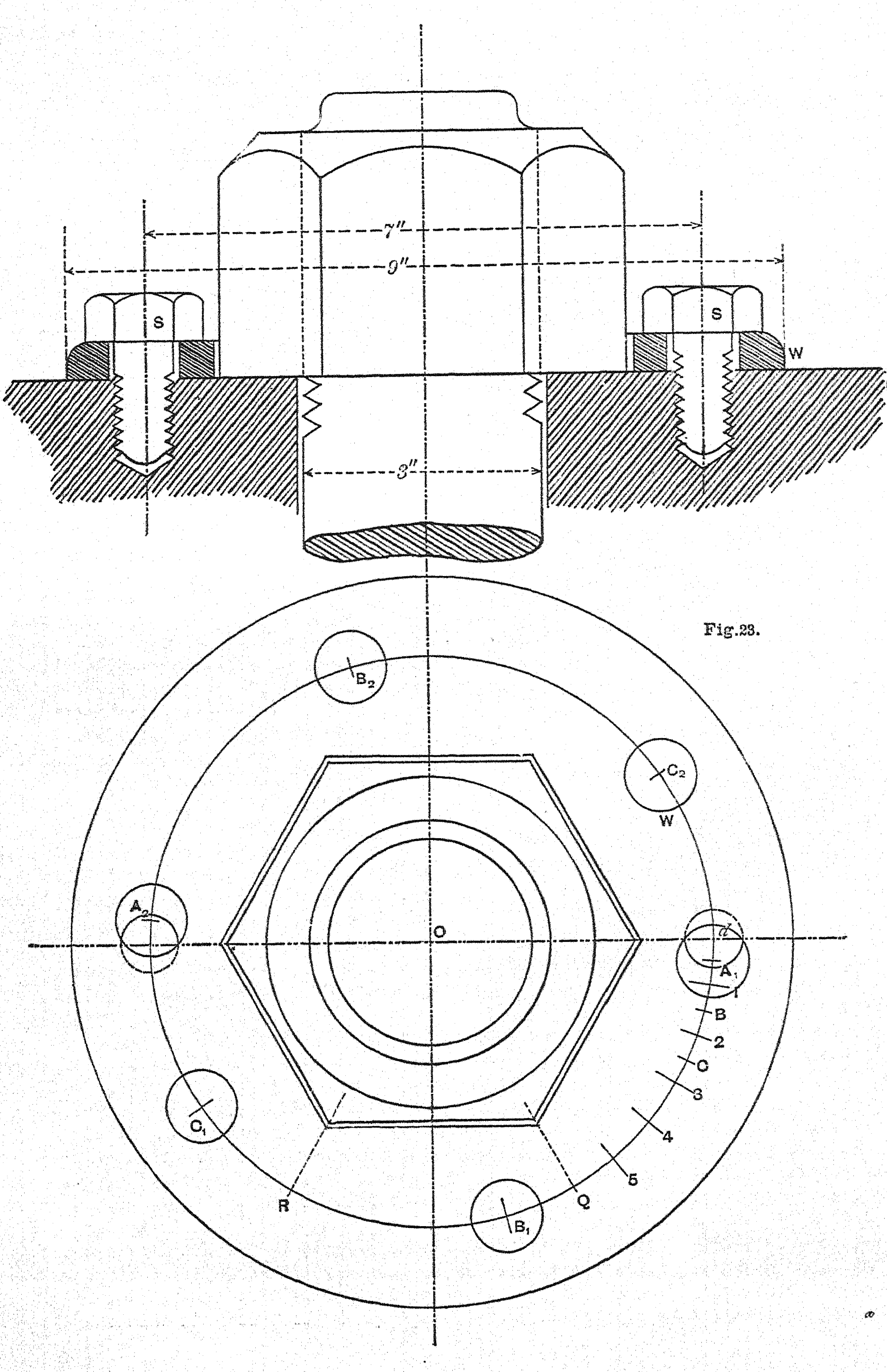


Fig. 23.

circumferentially, the washer could be fixed in any position of the nut, while the possible amount of slackening back of the nut would be equal to this additional length of hole.

DYEING OF TEXTILE FABRICS.—II.

By Prof. J. J. Hummel, F.C.S.

Professor and Director of the Dyeing Department of the Yorkshire College, Leeds.

[*Continued from p. 52.*]

FLAX, JUTE, CHINA GRASS (*continued*).

17. *Hackling.*—The subsequent *Hackling*, or *Heckling*, has for its object a still further separation of the fibres into their finest filaments, by combing, either by hand or machine. The product of the operation is twofold, namely, "flax-line" and "tow"; the former consists of the long and more valuable fibres, the latter, of those which are short and more or less tangled.

18. *Flax-Line.*—The appearance of flax-line is that of long, fine, soft, lustrous fibres, varying in colour from the yellowish-buff of the Belgian product to the dark greenish-grey of Russian flax. This difference in colour is chiefly owing to the system of retting adopted.

19. *Physical Structure and Properties.*—Examined under the microscope, a single flax fibre appears (Fig. 3) as a long, straight, transparent tube, often slightly striated longitudinally.

At irregular intervals it is slightly distended, and at these points faint transverse markings may be

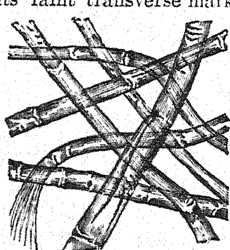


Fig. 3.—Flax Fibre under the Microscope.

detected. When examined with high powers they seem to consist of a succession of very minute fissures, and, according to Vetillart, are simply breaks, or wrinkles, produced by a bending of the fibre, and not cell divisions, or nodes, as frequently stated.

In transverse section, the linen fibre shows thick walls, an exceedingly minute central canal, and a more or less rounded polygonal contour.

The chief physical characteristics of the linen fibre, when freed from all encrusting material, are its snowy whiteness, silky lustre, and great tenacity.

Linen is hygrometric to about the same degree as cotton, and contains, when air-dry, about three per cent. of moisture. It is a much better conductor of heat, and therefore feels colder than cotton. It is also less pliant and less elastic.

20. *Chemical Composition.*—Treated with sulphuric acid and iodine solution, the thick cell wall is coloured blue, while the secondary deposits, in the central canal, acquire a yellow colour. The linen fibre consists therefore essentially of cellulose, but in its raw unbleached state it contains about 15-30 per cent. of foreign substances, chiefly pectic acid. Fatty matter, to the extent of about 5 per cent., colouring matter, and other substances not investigated, are also present.

Action of Various Agencies on Flax.

Pure linen fibre, being cellulose, the action of various chemical agents on it is much the same as on cotton, but generally speaking, linen is more susceptible to disintegration, especially under the influence of caustic alkalis, calcium hydrate, and strong oxidising agents, *e.g.*, chlorine, hypochlorites, etc.

The linen fibre is less readily dyed than cotton; its thick cell-walls and general physical structure and the possible presence of pectic matters no doubt exercising some restraining influence.

21. *Jute* consists of the bast fibres of various species of *Corchorus*, notably *C. capsularis*, belonging to the family of the *Tiliaceæ*, and is mainly cultivated in Bengal. The fibre is separated from the plant by processes similar to those employed in obtaining the flax fibre, namely, retting, beating, washing, drying, etc. The raw fibre, as exported, consists of the upper five-sixths of the isolated bast, and occurs in lengths of about seven feet. Under the microscope, it is seen to consist of bundles of stiff, lustrous, cylindrical fibrils, having irregularly thickened walls, and a comparatively large central opening. The colour of the fibre varies from brown to silver-grey. It is distinguished from flax by being coloured yellow under the influence of sulphuric acid and iodine solution.

According to Cross and Bevan, the substance of the jute fibre is not cellulose, but a peculiar derivative of it, to which the name *bastose* has been given. Under the influence of chlorine, a chlorinated compound is produced, which, when submitted to the action of sodium sulphite, develops a brilliant magenta colour. This colour reaction is also exhibited by tannin-mordanted cotton, with which jute shows great similarity; this is further exemplified by the fact that jute can be readily dyed in a *direct* manner with basic coal-tar colouring matters, *i.e.* exactly like tannin-mordanted cotton.

Jute may indeed be considered as consisting of

cellulose, a portion of which has become more or less modified throughout its mass into a tannin-like substance.

Acids, notably mineral acids, even at low temperatures, readily disintegrate jute, resolving it into soluble substances. This destructive action of acids must be specially borne in mind by the dyer and bleacher of jute.

22. *China Grass.*—This fibre, also called Rheea, Ramie, etc., consists of the bast cells of *Boehmeria nivea* (*Urtica nivea*), a perennial shrub belonging to the nettle family, *Urticaceæ.* The plant grows abundantly in China, Japan, and the Eastern Archipelago generally. No perfectly satisfactory method of obtaining the fibre with little loss has yet been devised, the ordinary retting process not being thoroughly effective. The chief characteristics of the fibre are its excessive strength and durability, fineness, silky lustre, and pure white colour. Sulphuric acid and iodine solution colour it blue, hence it consists essentially of cellulose. Under the microscope the fibres appear stiff and straight, and very similar to those of flax.

WOOL.

23. *Varieties of Wool.*—By the term "wool" we describe the hairy covering of several species of mammalia, more especially that of the sheep. It differs, however, from hair, of which it may be regarded as merely a variety.

Many mammalia have both wool and hair, and it is probable that this has also been the case with the sheep in its original wild state, but under the influence of domestication the rank hairy fibres have largely disappeared, while the soft under-wool has been singularly developed.

The climate, breed, food, and rearing of the sheep all influence the quality of the wool.

Sheep's wool varies from the long, straight, coarse hairy wool of certain varieties of the English sheep (Leicester, Lincolnshire, etc.) to the comparatively short, wavy, fine, soft true wool of the Spanish Electoral sheep.

Very marked differences exist even in the wool of a single animal, according to the part of the body from which it is taken, and it is the duty of the *wool-sorter* to distinguish and separate the several qualities in each fleece.

24. *The Physical Structure* of the wool fibre is very characteristic, and enables it to be readily distinguished from other textile fibres. It is built up of an immense number of epithelial cells, and under the microscope is seen to consist of at least two parts, sometimes three.

(1) The external cells appear as thin horny plates or scales of irregular shape, arranged side by side and overlapping each other, somewhat after the manner of roof-tiles (Fig. 4). The upper edges are more or less free, the lower are apparently imbedded in the interior of the fibre. In merino *wool* the

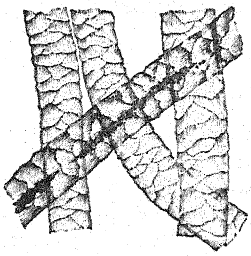


Fig. 4.—Microscopical Appearance of Wool Fibre.

scales appear funnel-shaped, and fit into each other, each one entirely surrounding the fibre. In *hair* they are more deeply embedded; they also lie flatter, and present but little free margin.

This surface character plays an important part in causing the "felting" of wool in "milling," etc. During this and similar operations the opposing scales of different fibres gradually become interlocked.

(2) The cortical substance of the wool, constituting nearly, and sometimes entirely, the whole internal portion of the fibre, is composed of long spindle-shaped cells. This structure, which gives the inner portion of a wool fibre a fibrous appearance, is best seen after gently heating with sulphuric acid.

In Fig. 5, B represents the microscopic appearance of the fibre after treatment with acid, and A shows some of the individual cortical cells.

It is an interesting fact that these disintegrated internal cells possess a greater attraction for colouring matter than the external scales, which seems to explain why "extracted" or "carbonised" wool dyes a deeper shade and more rapidly than ordinary wool.

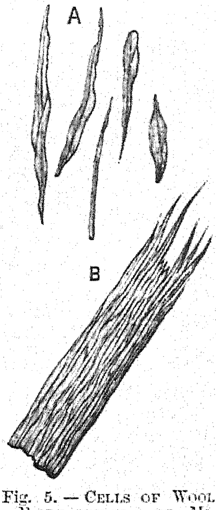


Fig. 5. — Cells of Wool Fibre under the Microscope.

(3) The central, or medullary, portion of the wool fibre is formed of rhombic or cubical cells, which appear as the marrow or pith of the fibre, and may traverse its whole length, or appear only in parts. In good classes of wool (merino, etc.) it seems to be entirely

absent, or rather it is indistinguishable from the cortical portion.

Wool fibres which exhibit the medullary cells are of lower quality than those in which the medullary cells are invisible.

Fig. 6 gives the cross sections, according to Dr. F. H. Bowman, of two typical wool fibres: A

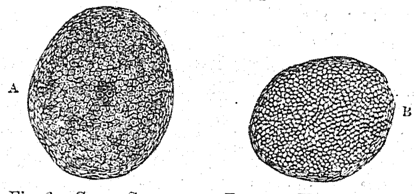


Fig. 6.—CROSS SECTION OF TYPICAL WOOL FIBRES.

shows the medullary, cortical, and external cells; in B the medullary cells are absent.

"Kemps" are certain wool fibres not possessing the normal structure of good wool; the scales are less distinct, or even invisible, and the whole substance of the fibre seems more or less opaque. They are very deficient in tenacity, lustre, and felting power, and in their attraction for colouring matters. (*See* "Woollen and Worsted Spinning.")

25. *Foreign Wools.—Alpaca, Vicuna*, and *Llama* wool are obtained from different species of the genus Auchenia (*A. alpaca, A. vicugnia, A. llama*), which inhabit the mountains of Peru and Chili.

Mohair is obtained from the Angora goat (*Capra hircus angorensis*) of Asia Minor.

Cashmere consists of the soft under-wool of the Cashmere goat (*Capra hircus laniger*) of Tibet.

The soft under-wool of the camel, which it sheds each spring, is also used. Of all these, the alpaca and mohair are most largely employed.

Certain of these foreign wools, more especially Van Mohair, also Alpaca, Camel's hair, Cashmere, and Persian wool, are apt to be dangerous to the health of the wool-sorter. They often contain the microscopic organism known as *Bacillus anthracis*, the same which excites splenic fever in cattle and horses. When taken into the bronchial tubes of man, it induces a kind of blood-poisoning known as "wool-sorter's disease." The wool-sorting rooms ought therefore to be well ventilated, and the sorters should if possible wear respirators during their work.

26. *Physical Properties — Hygroscopicity.*—The wool fibre is capable of absorbing a large amount of water without appearing damp, *i.e.*, it is very *hygroscopic*. Exposed to the air in warm dry weather, it contains 8 to 12 per cent. moisture; but if kept for some time in a damp atmosphere, it may take up as much as 30 to 50 per cent. It is noteworthy that damp wool is not so liable to mildew as the vegetable fibres are.

The amount of moisture in unwashed wool varies with the fatty matter it contains, the less fat the more moisture.

This hygroscopic character of wool renders it very desirable that those trading with it should know exactly its condition in this respect at the time of buying and selling, hence, on the Continent, so-called "Wool-conditioning" establishments have been instituted in various centres of the woollen industry—*e.g.*, Roubaix, Rheims, Paris—where the exact amount of moisture as well as the foreign matter in any lot of wool may be officially determined. These establishments are arranged on the same principles as those for silk-conditioning. The legal amount of moisture allowed on the Continent is 18·25 per cent.

If a wool fibre is steeped in warm water, it softens very considerably, and then, like all horny substances, it becomes *plastic*, retaining any position which may be forced upon it.

Elasticity is another important feature possessed by wool in a high degree, not merely because of the wavy character of the fibre, but also on account of its substance and structure.

The hygroscopic and plastic nature of wool come into play in the processes of "crabbing" and "steaming" of unions, in the "boiling" and "finishing" ("hot-pressing") of woollen cloth, and in the "stretching" of yarn.

Further, in conjunction with pressure, friction, and temperature, many of the above-mentioned physical features—*e.g.*, the scaly surface of the fibre, its waviness, and its hygroscopic, elastic, and plastic nature—play a most important part in the processes of "felting" and "milling" woollen cloth.

The *lustre* of wool varies very considerably. Straight, smooth, hairy wool has more lustre than the curly merino wool. The differences exhibited depend chiefly upon the varying arrangement and transparency of the scales on the surface of the fibre; the flatter these are and the more they lie in one plane, the greater will be the lustre. Such wools as possess a silky lustre in a high degree—*e.g.*, Lincoln and Leicester wools, etc.—are classed as *lustre wools*, as distinguished from *non-lustre wools*—*e.g.*, Merino, Colonial, etc.

Hairy, lustrous wool is harder and more horny than non-lustre wool, and does not dye so readily.

The best wool is colourless, but lower qualities are often yellowish, and sometimes variously coloured—*e.g.*, black, brown, red, etc. These natural pigments are not so fast to light as is generally supposed, a fact which is already revealed

by the bleached appearance of the exposed portions of the fleece.

The worth of any quality of wool is determined by carefully observing a number of its physical properties—*e.g.*, softness, fineness, length of staple, waviness, lustre, strength, elasticity, flexibility, colour, and the facility with which it can be dyed. *Fleece wool*, as shorn from the living animal, is superior in quality to "*dead wool*" (*i.e.*, wool which has been removed from the skin after death), if lime has been used in the process, as is usual with tanners, but if it be removed from the skins by cutting, the wool is practically equivalent to "fleece wool." Limey wool should always be treated with dilute hydrochloric acid and then washed with water previous to scouring.

27. *Chemical Composition.*—In considering the chemical composition of wool, a distinction must be made between the *fibre proper* and the *foreign matters* encrusting it. The latter consist partly of mechanically adhering impurities derived from without, but they are mainly secreted by the animal, and constitute the so-called *yolk* (Fr. *suint*).

Wool fibre which has been entirely freed from these foreign matters possesses a chemical composition very similar to that of horn and feathers, and consists of what is termed *keratin* (horn-substance). Its elementary composition varies somewhat in different qualities of wool, but the following analysis of German wool may be taken as representative:—

Carbon	49·25 per cent.
Hydrogen	7·57 ,,
Oxygen	23·66 ,,
Nitrogen	15·86 ,,
Sulphur	3·66 ,,
	100·00

The question as to whether the sulphur is an essential constituent or not has been much discussed. Its amount varies in different wools from 0·8 to 3·8 per cent. Its constant occurrence, and in comparatively large proportion, precludes the idea that it is merely an accidental constituent; moreover, it appears to be present in two modifications, and it has hitherto been found impossible to deprive wool *entirely* of its sulphur without at the same time destroying it.

This presence of sulphur in wool is attended with some practical disadvantages. The wool, especially when in an alkaline condition, is apt to contract dark-coloured stains, hence its contact with such metallic surfaces as those of lead, copper, and tin should be avoided during processes of scouring or even dyeing.

A boiling solution of plumbite of soda at once blackens wool, and may thus, in some cases, serve to distinguish it from silk or cotton.

When dyeing certain pale shades, much of the sulphur may be usefully removed by steeping the wool in cold weak alkaline solutions—*e.g.*, milk of lime—then washing it in water, in weak hydrochloric acid, and again with water, repeating the operations several times. Wool thus treated, though still containing sulphur, but evidently in some other form, does not react with plumbite of soda.

Action of Various Agencies on Wool.

28. *Action of Heat.*—If heated to 130° C., wool begins to decompose and give off ammonia; at 140–150° C. vapour containing sulphur is disengaged.

When a wool fibre is inserted in a flame, it burns with some difficulty, emits a disagreeable odour of burnt feathers, and a bead of porous carbon is formed at the end of the fibre. These reactions serve to distinguish wool from all vegetable fibres.

A cold ammoniacal solution of cupric hydrate has no action upon wool, but if it is used *hot* the wool is dissolved. Hair is less susceptible and does not dissolve.

29. *Action of Acids.*—Dilute solutions of *hydrochloric* and *sulphuric acids* have little influence upon wool, whether applied hot or cold, further than opening out the scales and making the fibre feel somewhat rougher. It is important to remember, however, that the wool attracts or absorbs a considerable proportion of the acid presented to it, which it is extremely difficult to remove by washing or even boiling with water. Wool boiled with dilute acid and afterwards with water may be dyed with acid coal-tar colours without the usual addition of acid. When treated with too concentrated acids, the fibre is soon disintegrated, but in any case their destructive action is by no means so energetic on wool as on cotton. This fact is made use of to separate cotton from wool in the process of "extracting" or "carbonising" rags containing both fibres. The rags are steeped in dilute sulphuric acid, and after removing the excess of liquid, are dried in a stove at about 110° C. The disorganised cotton can then be beaten out as dust, while the wool remains comparatively little injured. Another method is to submit the rags for a few hours to heated hydrochloric acid gas.

By heating wool with concentrated hydrochloric acid, it gradually becomes almost entirely dissolved, the solution containing so-called *lanuginic acid*, a substance which is said by some to play an essential part in certain cases of dyeing.

PRACTICAL MECHANICS.—II.

By R. Gordon Blaine, M.E.

Assoc. M. Inst. C. E., &c.; Senior Demonstrator and Lecturer on Mechanical Engineering and Applied Mechanics at the City and Guilds of London Technical College, Finsbury.

[*Continued from p. 56.*]

FORCES ACTING *not* THROUGH ONE POINT—WORK AND ENERGY—PERPETUAL MOTION—REPRESENTATION OF WORK BY AN AREA—WORK DONE BY A VARIABLE FORCE—WORK WITH ANGULAR MOTION—LAW OF MOMENTS.

THE forces we have to deal with in mechanics often act in one plane, but seldom through one point. Thus in the case of a beam, or a roof truss, loaded in the usual way, the forces are co-planar, but do not act at a point. How do we find the resultant of such forces? Well, there is certainly a little more difficulty in this case than in the cases previously taken up, for we have to determine not only the magnitude, direction, and sign of the resultant, but also its position in the plane. To do this, an additional construction is required, which will now be explained. In Fig. 9 we have drawn four forces not acting through one point. Notice how we name the forces. Each *space* has a letter assigned to it, and the force A B is that which separates the space A from the space B. In Fig. 10 the force is represented in the usual way by a line with a letter at each end. In Fig 10 the force polygon A, B, C, D, E is drawn, and the closing side E A gives the magnitude, direction, and sign of the resultant. The only point to settle now is to find the place in the plane where this resultant acts, *i.e.*, to find one point on the line of action of the resultant.

To do this we require the aid of what is called a "funicular" or "link" polygon. Choose any point or pole, O, near the force polygon, and draw a line from it to each corner of the force polygon, as shown in dotted lines in Fig. 10. Now take *any* point on one of the forces (say A B) in Fig. 9, and through the space A draw a line parallel to O A in Fig. 10, through space B a line parallel to O B, and meeting the last line on A B; through C a line parallel to O C, and so on, until each space has its dotted line; these dotted lines (Fig. 9) form the "link polygon."

Now close the link polygon by producing the lines in A and E till they meet at P, which is a point on the resultant. The resultant is now completely known.

It will be proved in a later lesson—what is here taken for granted—that if forces acting in one plane, but not through one point, are in equilibrium, their *force polygon is closed*, and also the *link polygon is closed.*

This agrees with the conditions already given, that the sum of the horizontal and also the sum of the vertical components of the forces shall be zero, *together with* the additional condition that the sum of the moments of the forces about any selected point on the plane shall also be zero. The term "moment" will be explained presently.

It will be noticed that it does not matter what point—on the plane—is selected for the pole O, except that if chosen in an inconvenient position the drawing may be of awkward dimensions.

Nor does it matter what point on the line of action of one of the forces is chosen to begin the funicular polygon; if the drawing is properly

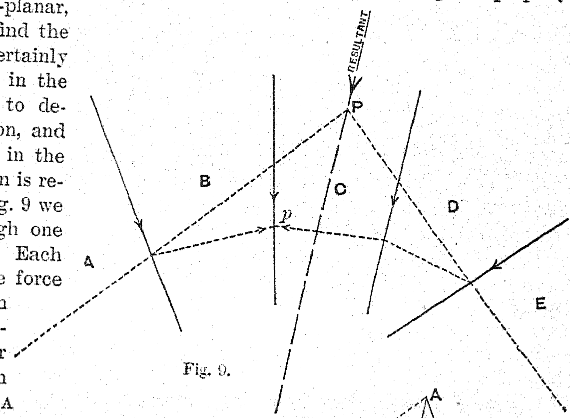


Fig. 9.

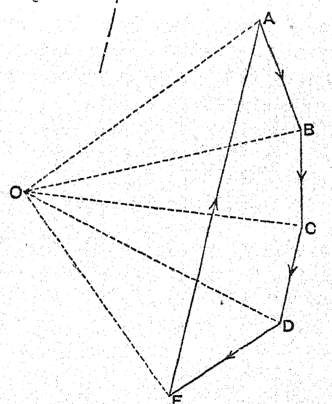


Fig. 10.

carried out, a point (not necessarily the *same* point) on the resultant will be found. It is very easy to put these statements to the proof.

The student should work examples by the various rules given in this lesson, and try to get familiar with the methods explained.

WORK AND ENERGY.

Work in its ordinary sense is a familiar word. We probably think of work most in connection with

the putting forth of muscular effort, and with the sensations of fatigue which usually follow. In the sense in which the term is used in mechanics, work is done when a *force is exerted through a distance* measured in its own direction. Thus, for instance, I may push with a stick against a wall, and may feel tired if I continue my efforts long enough, but I do no *work* if the point of application of the force does not move in the direction of the push. Here there is a force exerted but no *distance*, hence no work done. Again, one can imagine a piece of very smooth marble resting on ice; if the surfaces in contact were perfectly smooth, no work would be done in drawing the block over the ice. Here the distance exists but the *force* is zero. Perhaps the simplest case of doing work is that of lifting a weight, and hence this has been chosen to determine our unit of work,—the work done in raising a pound weight 1 foot high at sea-level at Greenwich being called one "foot-pound." The opposing force is in this case the attraction of gravity. In all cases in which work is done it is quite evident that there must be an opposing force or resistance of some kind, and we say that work is done *on* or *against* this resistance. If we look at the action from the point of view of the applied force or effort, we say that *energy is exerted*, but from the point of view of the resistance *work is done*.

Work, then, can be done by a body possessed of energy, and in fact the two terms work and energy are two names for the same thing when looked at from two different standpoints.

Energy then may be defined as the *power* or *capability of doing work*. And it is, on a little consideration, evident that nature has been most prodigal in her gifts to us in regard to this valuable quality.

The moving air or wind, the water in our rivers and streams, our great stores of coal and other fuels, and even the tides which ebb and flow on our coasts are all nature's precious gifts to prodigal man. One pound weight of good coal contains about 11,000,000 "foot-pounds" of energy, and yet when we burn $1\frac{1}{2}$ lb. of this coal in the furnace of one of our best steam engines, we will probably not get out more than $33{,}000 \times 60$ or 1,980,000 foot-pounds of energy. Hence, even in a steam engine, which is one of our most perfect machines, we waste at least $\frac{7}{8}$ of the energy which has been so providentially laid up for us; but it may be questioned whether, with this knowledge, we are wise in putting a vague dependence on the appearance of a new store of "fuel-energy" when our present one is spent. It must not be thought that the energy which is usually spoken of as *wasted* disappears altogether; it is merely changed into another form in which it is no longer useful to us. Heat is a low or degraded form of energy, and wherever rubbing takes place friction reduces some of our higher mechanical energy into this lower form. But the sum total of energy is the same as before, though it may have taken several different forms. Energy can neither be created nor destroyed by any process with which man is acquainted—this great law is called the law of the conservation of energy, and is perhaps the most important with which we have to deal.

It directly affirms the *impossibility of a perpetual motion*, for it is impossible to construct a machine in which there is absolutely no *waste*, in the sense above referred to, of energy; and hence less energy in the higher form is got from the machine than is put into it. It is evident then that, if we start with a given store of energy, and simply make it go round and round the cycle of the machine—as in the case where a water-wheel pumps up water which again drives, or helps to drive, the wheel—a time must come when the energy with which we started will all be wasted, or will all have assumed a lower form, and hence our machine must stop unless supplied with a fresh store. It is true that people have suggested the taking of heat from the air, which has practically an unlimited supply of energy in this form, and making it do work in cooling down to a lower temperature, but this too is a failure, as might have been foreseen from an elementary law similar in effect to that which we have stated. If we give one foot-pound of energy to a machine, and there is no *storage* and no *waste* of energy, we will get one foot-pound in the same or some other form from it, but *no more*. This is sometimes called the LAW OF WORK, and it at once disposes of the "perpetual motion" fallacy. It is of course evident that energy can exist in different *forms*. Thus, a weight raised to a certain height, or which can fall to a lower level, possesses energy in the form which we call *potential* energy. A moving body such as a projectile or a train possesses energy in virtue of its motion, this is called *kinetic* energy. A coiled spring possesses strain energy, which is a kind of potential energy, and chemical elements which can give out energy in combining, such as gunpowder, or any fuel, possess another form of energy—the energy of chemical affinity—a kind of potential energy. There are many other forms of energy, such, for instance, as those revealed to us by the sciences of electricity and magnetism; but the great law is still true, that if one foot-pound of energy in any form makes its appearance, one foot-pound at least, in the same or some other form, must have disappeared.

REPRESENTATION OF WORK.

Since work is the product of two things—*force* and *distance*—it is evidently such a quantity as we may represent by an area. This is very easily understood in the case of work done by a constant force, for in this case the area is a rectangle. Thus in Fig. 11 let the height O B contain as many

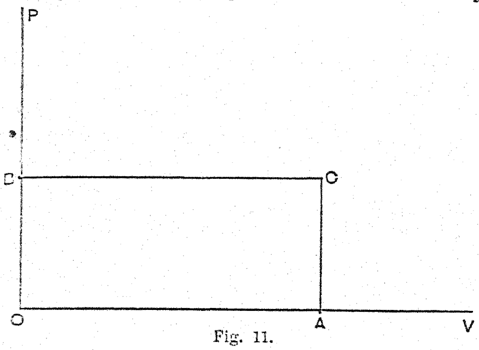


Fig. 11.

units of length as there are units of force in the constant force; and let O A be of such a length as

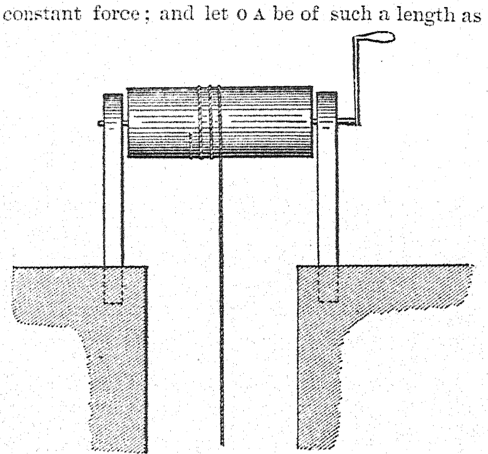


Fig. 12.

to represent to some scale the distance through which the force acts, then the area of the rectangle O A C B will contain as many units of area as there are units of work in that done by the force. Thus the area *represents* the work done in this case. In practice, however, the cases in which we have to deal with constant forces are comparatively few. One simple instance of work done by a *variable* force is that in which a chain or weight of a similar nature is raised by a force acting at one end of its length. Thus in Fig. 12 we have a chain suspended by one end. Suppose the chain is l feet long and weighs w lb. per foot, find the work done in raising any given portion, say b feet, of it.

The simplest and most practical solution is a graphic one. Draw a horizontal line A B (Fig. 13) to represent the total length of the chain, and at one end erect an ordinate A C to represent the total weight of the chain; join C B. Then from A measure off A D to represent b feet of the chain, and draw D E

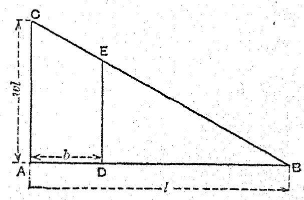


Fig. 13.

parallel to A C: D E will represent the weight of chain hanging down after b feet have been raised, the area of the whole triangle will represent the work necessary to raise the whole chain, the trapezoid A D E C will represent the work required to raise the first b feet of it, and the triangle E D B that required to raise the remainder.

It is evident from the similarity of the triangles that

$$\frac{CA}{AB} = \frac{ED}{DB} \text{ or } \frac{wl}{l} = \frac{ED}{l-b},$$

$$\therefore ED = w(l-b).$$

Now the area of $ADEC = \frac{1}{2}(AC + DE) \times b$

$$= \tfrac{1}{2}\{wl + w(l-b)\} \times b$$

$$= w\left(l - \frac{b}{2}\right)b.$$

This is the number of units of work required to raise the first b feet of the chain. The work required to raise the whole chain is evidently $\frac{1}{2}wl \times l = \frac{1}{2}wl^2$ or $=$ weight of chain $\times\ \frac{1}{2}$ its length.

These results involve an important principle connected with centres of gravity, which will be referred to later on. The reader will notice that the work is in each case simply the *weight multiplied by the height through which the centre of its mass is raised.*

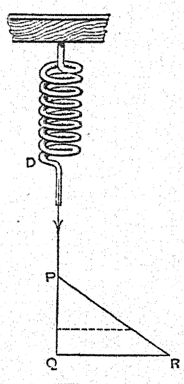


Fig. 14.

Another very common instance of work done in a similar way is that of extending a spiral spring. Thus in Fig. 14 a force is applied to elongate the spring. At first when the force is zero the position of a point attached to the spring is, say, at P, and an increasing force is gradually applied till this point reaches Q, the line Q R representing the force then necessary to balance the pull of the spring. Any line in the triangle parallel to Q R shows the force necessary when the spring has been elongated

a distance represented by the length from P to that line; and the work done in elongating the spring to Q, represented by the area of the triangle PQR, is therefore half the final pull of the spring multiplied by the elongation, or is equal to the final pull of the spring multiplied by half its final elongation.

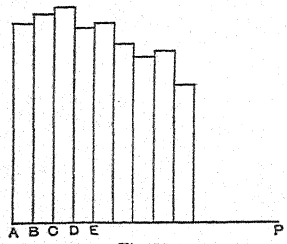


Fig. 15.

If the force varied in the curious way represented in Fig. 15—where it is constant through a short distance represented by the breadth of a little rectangle and then suddenly changes to a new value, shown by the height of the next rectangle and so on—the sum of the areas of the little rectangles will represent the work done by the force when varying in this curious way. Now let the little distances A B, B C, etc., become smaller and smaller, *i.e.*, let the distance through which each value of the force acts become less and less: in the limit the force will vary, not by sudden jumps, but in a regular way, and the top of the figure will be a regular curve; the area included by the curve, the two end ordinates, and the line A P still representing the work done. This is a very important result, which will be referred to in connection with the steam engine indicator and indicator diagrams.

WORK AND ANGULAR DISTANCE.

In the preceding the point of application of the force is supposed always to lie on a straight line. But it is evident that work may be done in turning a body about an axis, and I shall now briefly refer to this part of the subject.

Imagine two forces P and Q acting on a lever

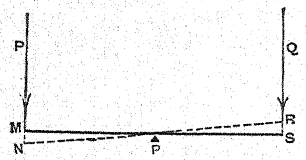


Fig. 16.

balanced on a knife-edge at P, and moving under the action of the forces from the position R N to the position of equilibrium M S, as shown in Fig. 16. Neglecting the weight of the lever, and imagining the motion very small, the work done on P is $P \times MN$, that done by $Q = Q \times RS$, and these two amounts must be equal since there is no waste of energy;

But $\frac{MN}{MP} = \frac{RS}{SP}$ or $\frac{MN}{RS} = \frac{MP}{SP}$, because the triangles N M P and R S P are similar;

$$\therefore P \times MN = Q \times RS$$

may be written

$$P \times MP = Q \times SP.$$

Each product is called the "moment" of the force about P,* and the *law of moments* is simply the law stated above, viz., that if forces act on a body which is free to turn on an axis, then if there is equilibrium the *sum of the moments of the forces about the axis must be zero*, different signs being given to moments which tend to turn the body in opposite directions. A more complete proof of this important law is given in the lessons on "Applied Mechanics" in the NEW POPULAR EDUCATOR. A few practical applications of this law will probably be of interest.

CARPENTRY AND JOINERY.—II.

BY B. A. BAXTER.

[*Continued from p. 61.*]

TOOLS (*continued*).

ALTHOUGH most of the carpentry work of building construction will be done on rough timber, and the plane is the typical tool of the joiner, yet the carpenter had better provide himself with a plane or two. A jack plane will probably do for the present. This plane is 17 inches long and usually has an iron $2\frac{1}{4}$ inches wide. It will be useful for reducing, when joining pieces not quite agreeing in width. If two planes are purchased, a trying plane will be the most useful addition to the stock. This is 22 inches long, and the iron ought to be at least $2\frac{1}{2}$ inches wide.

A gouge or two had better be added to the list of tools. Gouges may be useful in enlarging holes or countersinking, as well as for ordinary shaping purposes.

A lesson will be given upon some appliances for setting out, which are scarcely tools, and must generally be made by the worker. These will include various gauges, appliances for marking circles and ellipses, squares and angle bevels.

Trusses.—The most important parts of carcass carpentry are floors, partitions, and roofs, and the principle most relied on to secure stability in roofs and partitions is the fact that if the sides of a triangle remain unaltered, the angles remain unchangeable. This principle is at the base of all roof design, and is the justification for what is called "the truss." Roof principals and built-up girders invariably rely

* The distances MP and PS are supposed to be at right angles to the forces P and Q respectively.

on this simple but rigid rule. Modern practice has learned to recognise the great tensile strength of a comparatively small iron rod, and by using timber for all that is compressed by the strain, and iron rods for every portion that would be extended by the weight of the superincumbent structure, and taking advantage of the facility afforded by bolts

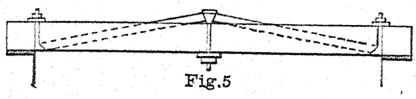


Fig.5

and nuts, their easy adjustment and the ready way in which holes for the reception of iron rods can be made in any direction through the timber, composite beams can be built up of greater strength

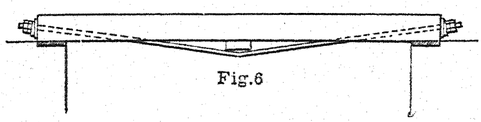


Fig.6

than would be possible of wood alone (*see* Figs. 5 and 6).

On examination it will be found that these inserted rods convert four-sided openings into

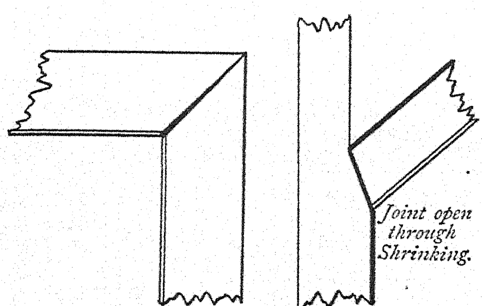


Fig. 7.

triangles. In oblique work, the abutments need special care, owing to the alteration of angle which takes place in the joint when such timbers shrink. An examination of any picture-frame that has been made of damp wood will show that the joints open at the inner corners as the frame dries, proving that diminution of width with unaltered length affects the angle of the mitres. It is generally agreed that the abutment of a joint should be as nearly as possible a right angle to the compressed timber, or that the angle should be bisected (Figs. 7, 8, and 9).

It is partly because of these difficulties, and partly to avoid cutting mortises in beams, that iron sockets are often employed.

The practical use of tools can only be attained by effort, and this work can help only by suggesting means to the desired end, and methods suitable to secure proficiency.

Joists and Sleepers.—Almost the first carpenter's

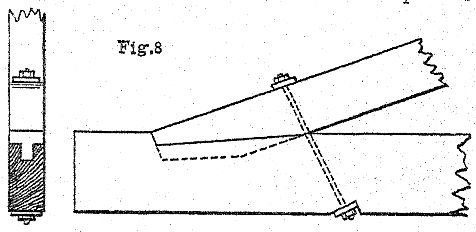


Fig.8

work required in the building is notching together and fixing joists and sleepers (Figs. 10 – 13). The notching drawn here resembles halving, but is not so deep, the cogging is like a bridle-joint but is not the same, and is shallower. The notching may be cut with the saw and chisel, and the

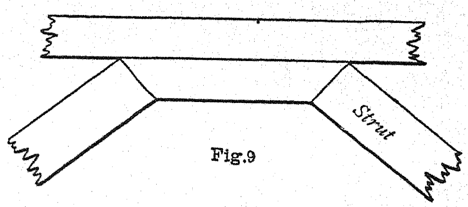


Fig.9

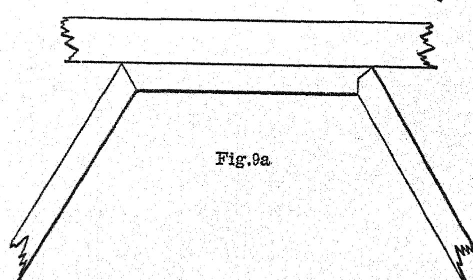


Fig.9a

cogging the same, except that the use of the saw is in cogging more limited. The sleepers rest on piers here and there, or on a little wall across the building, and are either supported by abutments or piers at each end. It depends upon the distance between the ground and the sleeper whether pier or wall is adopted; the sleeper serves as wall-plate to the joist, and neither wall-plate, sleeper, nor joist *should be built into* the wall in the basement, owing to the possibility of damp and decay. In fact it has been recommended to rest the joists of upper floors upon a plate not built into the wall but resting on corbels, but there is no reason to suppose that good timber will readily decay when built into an upper portion of a wall when sand and lime mortar is used.

Corbels.—These are brackets, or blocks of wood, stone, or any other suitable material, partly built into the wall and partly projecting from it. This

Fig.10

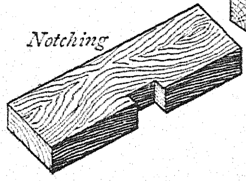
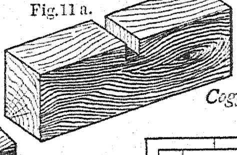


Fig.11 a.



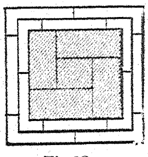
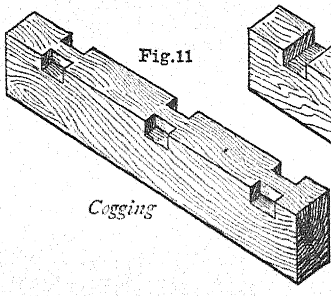


Fig.13 a.

Fig.11



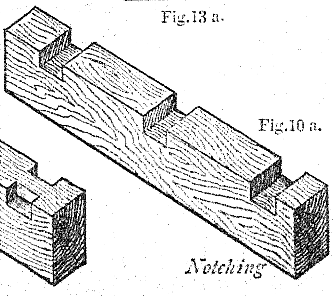


Fig.10 a.

projection, which serves to support any beam or frame, may be carved or ornamented in any way. The advantages of corbels are easy insertion where

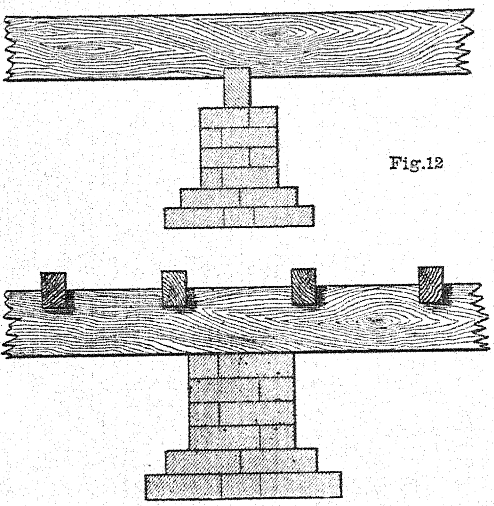


Fig.12

desired, ornamental appearance, utility in case of alterations, the defect being that the weight is not so well distributed as in a wall-plate (Figs. 14–16).

Notching and Cogging.—The sleepers will probably be laid before the notching is done. By means of a chalk line all the places for the joists can be marked, the ends of the notches sawn, and

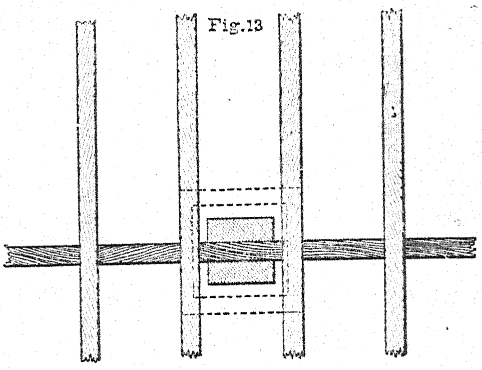


Fig.13

the waste wood removed with a chisel, taking care, both with saw and chisel, not to cut away too much. The flat side of the chisel will be found best for finishing, but the chisel may be used in any convenient and safe position to cut away the waste wood before the final cuts are made. The cogged joint will be a trifle more trouble, and the saw will not be so helpful: more will have to be done with mallet and chisel, because the cog is left on the middle of the sleeper.

The joists will be notched to fit the notch or cog, the difference is a mere matter of the width of the cut portion, and can be done with saw and chisel, as the notching of the sleepers was done. Care

Fig.14

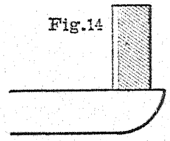
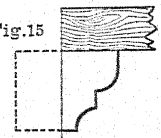


Fig.15



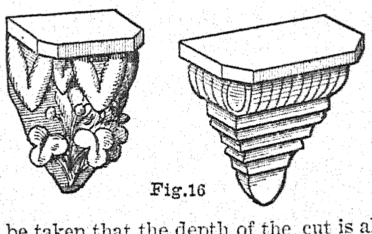


Fig.16

must be taken that the depth of the cut is alike in all joists and sleepers.

Partitions.—Probably the next work required of the carpenter will be making partitions. Partitions will demand treatment special to themselves. These, of which drawings are to be found in Figs. 17 to 20, involve the use of the "mortise" and tenon. The

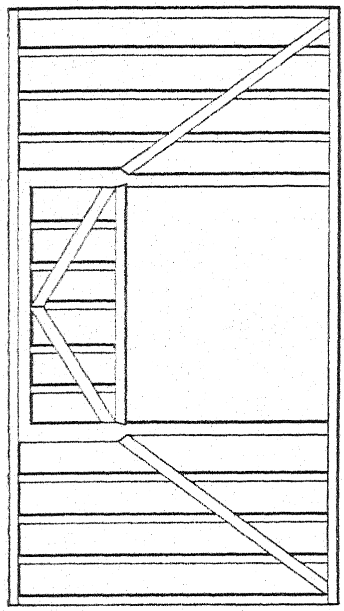


Fig.18

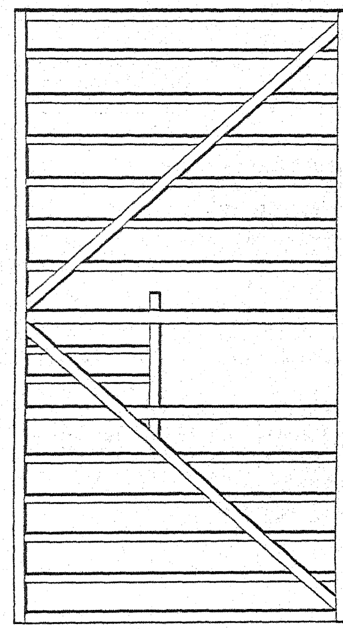


Fig.20

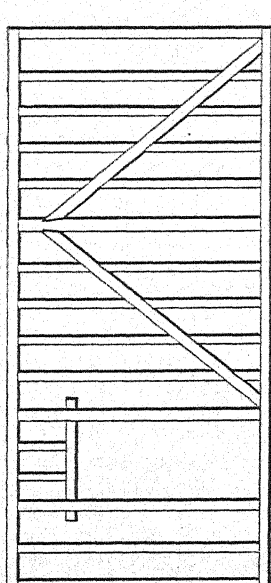


Fig.17

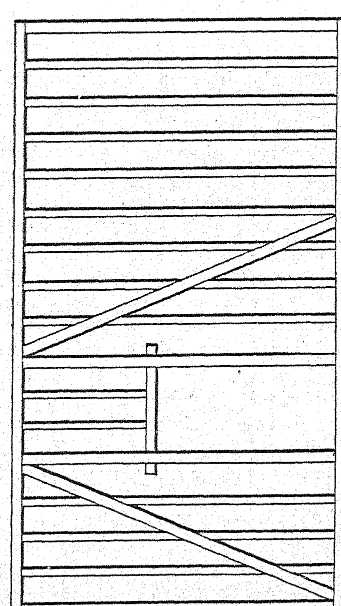


Fig.19

mortise is a rectangular cavity cut in the interior of a piece of wood; that is, a mortise, although it may be cut right through a piece of wood, must not extend to the end or either side of a timber, or it ceases to be called a mortise (Fig. 21). This joint is more frequently used than any other, and is comparatively simple to make. The breadth of the mortise, when cut in partitions, door frames, etc., is usually about one-third of the thickness of the wood, and a trifle more or less is of no serious moment. Depending as it does on the size of the chisel, the mortise is generally to the nearest size approaching the $\frac{1}{3}$, for which chisels are made.

Mortises may, however, be enlarged to dimensions greater than at first cut, but this is a waste of time, and the best plan in such a case is to obtain a larger chisel.

Labour may be saved by boring out as much of the wood of the mortise as possible; but the easy removal of the bulk of the wood is balanced, as far

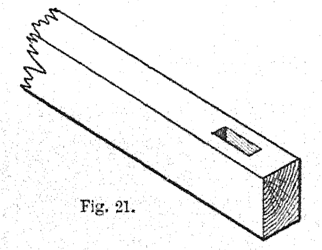


Fig. 21.

as time is concerned, by the necessary squaring of the cavity.

The accuracy of a mortise depends on (1) the timber resting on a level surface while being mortised; (2) on the worker's eye being in a plane with the centre of the mortise; (3) upon the chisel being ground and sharpened truly, and the handle being true to the blade. The first cuts in making a mortise should be near its centre, and as soon as possible some of the core must be removed; after which, each cut removing but a small piece of wood, must be driven deeper and deeper until the required depth is attained. Keeping the flat side of the chisel towards the boundary to which each successive stroke is tending, the chisel is little by little brought up to the line. When the full depth has been reached, make every succeeding cut as deep, and in every case have proper lines set out before mortising. The parallel lines for the mortise are marked out either with a pencil or with a mortise gauge. A pencil is accurate enough for unplaned wood, but for joinery the gauge ought to be used. A saving of time may be effected when several mortises alike in size are to be cut by making a mortise in a piece of thin wood and using it as a "template" (Fig. 22). The same template will serve to set out the tenons. These are cut with any suitable saw; if large, with a rip-saw, and the shoulders with a hand or tenon saw.

A template is a pattern either in wood or in

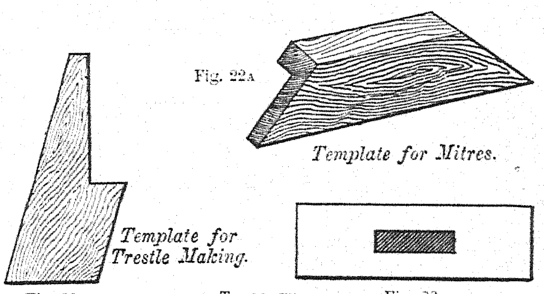


Fig. 22B. TEMPLATES. Fig. 22.

sheet-metal, which, being carefully prepared to the required dimensions, enables the workman more readily to shape several articles to the same figure. Templates are, therefore, used to mark the shape and position of any mortises or other cuttings required (Fig. 22) as well as the external shape of the work required (Fig. 22B).

The name is also applied to a guide for cutting "mitres" to right-angled frames. Such a template is made either of wood or metal, and has its ends cut at an angle of 45° to its longer edge. Although differing from templates in general, this mitre template serves the same purpose. It is equally a model by which the angle is determined (Fig. 22A).

Templates of sheet zinc will be found of great utility, and as the metal is not very hard it can be cut with any carpenters' tools or a pair of strong scissors. In cases where shaped brackets are required, the pattern may be drawn on the zinc with any pointed tool, or if the zinc is not quite bright, with a black lead pencil. If one of the edges of work is straight, the line may be drawn on the zinc a little distance from the edge, and a few cuts from the edge of zinc to the line will allow the metal to be bent alternately to the right and left at right angles to the face of the pattern, thereby forming a stop. Curved lines may be cut with gouges or bored out with centre bits, and straight lines cut with the aid of a straight edge and a strong knife, or even a bradawl. Such a template has been found of great service by the writer in making the ends of a number of seats for a chapel, the zinc template not only giving the outline for each end, but also indicating the housing cuts for the reception of the seats and back rails, and was equally available for either end.

WOOLLEN AND WORSTED SPINNING.—II.

By Walter S. B. McLaren, M.P.

[*Continued from p. 65.*]

THE NATURE OF WOOL (*continued*).

9. *Soundness of Fibre.*—The property of wool next in importance is soundness of fibre. It is clear that if the fibre is tender in the middle, it will break during some process of working, and thus the thread is weaker, and all value derived from length of wool is lost. Tenderness arises from ill health and neglect of the sheep, and is seen at once by the fibre being thin in some part; just as when a person is ill those portions of his finger-nails which are being formed during his illness grow and always remain thinner than the rest, so when a sheep is ill or half-starved, the portion of wool grown at the time is thin and tender. This can be most readily detected by pulling a small staple tightly from both ends, when if it be tender it will give way.

10. *Softness, Fineness, and Length.*—In softness, fineness, and length, wools vary according to the breed, and just as any wool combines all three qualities so it is valuable. Whether wool which is fine but short is more valuable than that which is stronger but long, depends on the use to which they are to be put. Very fine wool is never, however, of great length. Strong wools grow from one to twenty inches long. Lustrous wools belong to the longer and stronger varieties, fine wools are usually devoid of any gloss, but are very much softer to the touch.

11. *Colour.*—With regard to colour, other things being equal, wool which is pure white is most valuable, but there are some sorts of fine natural browns which are also much prized. The soil has much to do with the colour. Sheep which are fed on rich grass lands have pure white wool, but those fed on sandy and red-tinged soil become more or less yellow, and even after washing the wool is not the brilliant white which is seen in wool grown in clear pure air on good grass lands. Some wools are brown, black, grey, and even bright yellow; among these last are certain qualities of Egyptian and East Indian. These colours are due to the nature of the sheep, and are probably beyond the power of the farmer to alter.

12. *Felting.*—From what has been said it will not be difficult to understand the reason why wool can be felted, though the process and the machinery for carrying it on will not be described here. Felting is no doubt partly due to the wavy curling nature of the wool, which inclines it to twist round anything it catches, but it is chiefly due to the structure of the wool in the cells already described, and to the saw-like edges which they form. The serrated edges of the fibres fit into each other, and lock fast, under the pressure of heavy weights used in the process, and thus the piece of cloth which was formerly seen to be made of separate threads, after felting seems to be one solid mass. This process can only be carried on when the cloth or wool—for it does not need to be woven—is wet, and warm water is more efficacious than cold, while the addition of acid greatly facilitates it. There does not seem to be any definable limit to felting, and to what always accompanies it—shrinking. As anyone who uses flannel is aware, it continues to become more matted, thicker, and smaller in length and breadth every time it is washed. We have seen a piece of worsted cloth, with both warp and weft, made entirely of combed long English hog wool, shrink after two hours' milling into one-third of its former dimensions, and become like a piece of flannel. The reason appears to be that as the fibre is composed of countless little dried-up cells made originally of soft gelatinous membrane, when these are put into hot water, the cells partly expand, and become soft; if there is acid in the water, it acts so much more quickly on the membrane in softening it. A small fraction of the membrane may be entirely dissolved, but even where this does not take place the cells are made soft. They are then beaten or pressed with heavy weights, and so are squeezed, or to a certain extent even glued together, and just as the fibres in one thread are thus firmly joined, so the fibres in different threads are also united. It is not, however, merely a question of binding them together. They shrink in the process. The cells being once softened do not return to their former positions when dry again. They seem to shrink into each other more than before, and thus the fibre becomes thicker and shorter, and the cloth "runs up" to an indefinite extent. In cotton and linen there is no such shrinkage. It is this shrinking property whereby woollen cloth is made into a compact solid mass that makes it so suitable for clothing, because, being solid, the cold air cannot well penetrate it, and it is also a non-conductor of heat. Were it a conductor, it would afford no proper covering for sheep or other animals, for they have to depend on its non-conducting nature only, and not on its felting properties. These latter appear to be given to it entirely for the benefit of man; certainly they do the sheep no good, for if the wool felted on the sheep's back it would become full of dirt, besides being of little use to mankind. It may be asked why it does not felt on the sheep's back. It is often wet, which is

one requisite, and is rubbed and pressed when the sheep is lying down. The answer is simple: Because all the fibres are lying one way. The serrations, as has been said, always point in the direction away from the root of the fibre, and thus they cannot fit into each other any more than two saw-edges pointing the same way could interlock, or than two fir-cones could stick together if they both lay in the same direction. But reverse one of them, and then try to draw it past the other while touching it, and they will at once become fastened together. In like manner, during the various processes of manufacture, the fibres of wool are pulled about in every direction, and thus their edges are placed with many of the points facing each other, and ready to seize hold when the felting operation begins. Skin-wool, that is wool taken off the skin of a sheep after it is dead, is said to felt better than wool that is shorn. The reason of this is stated by Dr. Bowman to be that the lime or acid which is used to get the wool off "causes the scales to be less firmly attached to the shaft of the fibre and the free margins to stand out more prominently, and thus increase the felting property." It is thus not merely the number of serrations which causes wool to be specially suited for felting, but the prominence with which their points project. As will be seen, too, later on, this same property is of assistance in spinning, and is one of the reasons why fine wool is more easy to spin than coarse wool of greater length. The amount of grease and dirt which is in the wool while on the sheep's back also tends to prevent it from felting, as the serrations are more or less filled up, and thus unable to take hold of each other.

13. *Alpaca and Mohair.*—It is not within the scope of these lessons to give a special account of various kinds of wool, but alpaca and mohair require a few words of special mention. The former is the wool of the Alpaca goat, which is really a species of llama, a genus allied to the camel and dromedary. Its wool is very bright and soft, and in colour is white, brown, and black. Mohair, which comes from the Angora goat, is very long and silky, and is the brightest and most lustrous of all classes of hair or wool. The best and cleanest is white, and comes from the central districts of Asia Minor. Brown mohair is grown about two hundred miles south of Angora, and is much more dusty than the white, while Van mohair, from Lake Van, is a lower quality, and exceedingly dusty. The mohair goat is also reared in the Cape of Good Hope, and large quantities are imported from that district. Alpaca inclines to be a hair rather than a wool, as the scales lie closely attached to the centre of the fibre. Mohair, on the other hand, is a wool, and has both the curves and the projecting points of the scales. The processes of their manufacture are, in their main features, the same as those for wool. As alpaca and mohair are both valued for their lustre, they are not felted, and though, no doubt, they could be felted were it necessary, they are, for many reasons, unsuited to the process.

WOOL-SORTING.

14. *Hogs and Wethers.*—It is not enough merely to know the nature and properties of wool. It is necessary to be able to "sort" it. In the cotton trade there is comparatively little difficulty in this respect. The varieties of cotton are few, and each bale contains, or should contain, only one quality. But every fleece of wool contains six or eight different qualities, all of which must be separated from each other if an exact division is required, and as the number of varieties of sheep is really unlimited, the field open to the wool-sorter is indeed wide. The first point to be understood is the difference between the wool of lambs and one-year-old sheep, and that of sheep of two or more years of age. The former is called Hog, or Hogget, and is naturally pointed at the end, because it has never been clipped; the staples too, which each group of fibres forms, are also pointed and taper out into long thin ends. The latter is generally called Wether. The fibre ends having once been cut are never so pointed, and the staples have thick and rougher tips. Hog wool is more valuable, longer—being generally fourteen months' growth—finer in quality, and possesses more of that wavy curling nature which makes it cling to other fibres, thus assisting the process of spinning. On account of the difference in value it is necessary to tell at once a hog fleece from a wether. This can be done in two ways—either by examining the staple-ends to see whether they are pointed or thick; or if this is uncertain, as it sometimes is, by pulling a staple out of the fleece. If it be a wether, the staple will come clean out without interfering to any extent with the surrounding staples; but if it be a hog, some of the fibres of the other staples will adhere to the bottom of the one being pulled, and thus be dragged out after it. Hog wool is generally dirtier and fuller of moss, straw, or other vegetable matter; no doubt, because the lambs are less careful where they go than are older sheep.

15. *Different Qualities of Wool.*—To give an idea of how the qualities of wool vary, the following diagram (Fig. 2) has been prepared, showing approximately where each quality is to be found on an ordinary English sheep; but it must be observed that a wool-sorter accustomed to strong coarse

English fleeces would be at a loss how to proceed if placed before a pile of South Downs or fine Botany wool, because the latter being throughout so much finer, either has not the same range of qualities or is much more difficult to separate.

No. 1 is the shoulder, where the wool is long and fine; it grows the closest and is most even. No. 2 is rather stronger, but otherwise equally good; the best and soundest wool grows on these two parts. No. 3, on the neck, is shorter than No. 1, but even finer; where sheep are liable to have grey wool it is sure to be found here, and also on No. 4, which, with No. 5, grows wool of inferior staple and faulty character. No. 6, which covers the loin and back, is coarser and shorter, while on No. 7 the wool is long, strong, and hangs in large staples. On cross-bred sheep this part becomes very coarse, and is much the same as No. 8, which is the coarsest part of the wool, and is known as "breech," or "britch," and even, when very strong, as "cow-tail." When like this it almost resembles horse-hair, though it is more brittle, and not so smooth and bright. No. 9 is also strong, and much the same as No. 7. No. 10 is short, dirty, and increases in fineness as the front legs are approached; it is known as "brokes." No. 11 is also short and fine, while No. 12, the front of the throat, is short and worn with rubbing. Kemps, or dead hairs, are mostly found in Nos. 12 and 8, though in the latter they are much longer and stronger than in the former. No. 13 is the head, on which the wool is very short indeed, rough, and coarse. On the legs, No. 14, it is still worse, and of very little value. For the idea of this diagram I am indebted to the *Textile Manufacturer*, as also for the following table of qualities. It will be seen that the quality of the wool varies in the same way as the quality of the mutton. The shoulder of mutton is finer in grain and more delicate than the leg, and so is the wool; there is more wear and tear, too, for the sheep in its haunches than its shoulders, for the weight is chiefly there when it lies down; consequently the wool is longer and stronger. If the wool about the neck were as long as at the tail, the sheep could not get through hedges and briars, and it would also be weighed down while eating; therefore Nature provides that the wool shall be short and fine—just enough to keep the animal warm. The wool on the back becomes rough and thin, being most exposed to the rain, and because it naturally divides down the ridge of the back, it falls over to each side.

16. *Range of Qualities.*—As has been said, the range of qualities is not the same in sheep with fine wool as in those of stronger breeds. The different breeds may be compared to the key-board of a piano: each sheep has its octave of qualities, but the octave of the Merino sheep is very high,

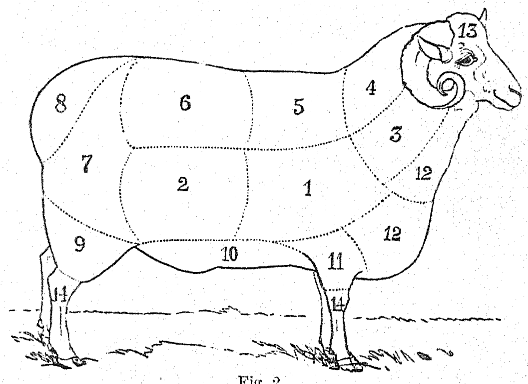


Fig. 2.

while that of the Lincolnshire sheep is very low. The table on page 128 shows the range for a number of varieties, and illustrates the principle well. English wools vary so much that it would require many tables to show their range. The range which each sheep has is not, however, very great, Lincolnshire wools being suitable for Nos. of yarn between 36's and 20's, Yorkshire wool between 44's and 20's, while South Down wools have a range at very much higher counts.

17. *Names of Qualities.*—Wool-sorters, however, do not call their qualities by the names of the parts of the sheep; they have names varying in different localities. In the woollen trade the following names are common for English wool:—picklock, which, as the name implies, is the choicest of all; prime, which is very similar; choice, a very little stronger; super, from the shoulders; seconds, the best bits from the breast; downrights, the strong wool of the side, marked No. 2; abb, which is between these two; breech, from the part marked No. 8; and head, from the head. In the worsted trade these names are not used, the following being those generally adopted:—blue, from the neck; fine, from the shoulders; neat, from the middle of the sides and back; brown-drawing, from the haunches; breech, or britch, from the tail and hind legs; cow-tail, when the breech is very strong; and brokes, from the belly and lower part of the front legs, which are classed as super, middle, and common, according to their quality. For finer sorts of wool there are no special names, and Botany and similar fleeces are sorted according to their numbers or the counts of yarn they will spin to, such as 50's, 70's, 80's, and so on.

18. *Form of the Fleece.*—When the wool comes into the sorter's hands, each fleece is rolled up into a ball by itself, and generally tied with a sort of rope made out of part of itself, the shoulder being often used for this purpose, as it can be twisted most conveniently into a cord. If properly wrapped up, the fleece should be quite easy to open, and when spread on the floor its different parts can be at once recognised. A thin ragged line, which represents the back of the sheep, divides the fleece in two, and by this the sorter separates the two halves, placing them on a pile at his side. He is furnished with a number of skeps equal to the number of sorts or qualities he has to make, and then spreading half a fleece on the bench before him, he proceeds with shears to clip off all pieces of tar and hard dirt, to pick out straws and other vegetable matter, and then separates the fleece into its different qualities. A perfect knowledge of these qualities can only be gained by years of experience; but when once acquired, the sorter knows as well by his hands as by his eyes where he shall divide the fleece, for it is not merely the coarseness or fineness of the fibre which guides him, but also the softness and kind "handle," as it is called. He is aided, too, by seeing the half-fleece stretched out before him, and therefore he knows where to expect each quality; but this is to him only a secondary matter. Some fleeces are much more difficult to open than others, and require either to be beaten or warmed. Fine Australian fleeces, which are packed in bales unwashed, and have perhaps 60 per cent. of grease on them, become quite hard if left cold, owing to the grease and dirt upon them becoming stiff, and they can only be opened by being pulled to pieces. They are therefore warmed, the grease on them softens, the fibres expand and are raised up, and the fleece opens quite easily. It will be seen later that wool is easier to work in certain processes when hot than when cold. The reason is that when cold, or pressed hard together, the fibres lie closer, their serrations fit into each other and become matted. Hence, they cannot be drawn out without risk of breaking, and without the expenditure of greater power. But when heat is applied, the fibres expand, and in doing so free themselves from each other, and can be drawn out with much more ease.

COMPARISON OF WOOLS OF DIFFERENT SOURCES, WITH THEIR DIAMETER, AND THE CORRESPONDING NUMBER OF YARNS.

Sorting Number.	Wool from							Suitable for Nos. of Yarn.	Diameter of the Filaments.
	Silesia.	Saxony.	Australia.	Champagne.	Spain.	North of France.	Algeria.		The unit is the millimètre.
1	Extra fine							225	From 0·015
2	Superfine	Extra fine						180	
3	Fine	Superfine	Extra fine					160	to
4	Semi-fine	Fine	Superfine	Extra fine				145	
5	Medium	Semi-fine	Fine	Superfine	Extra fine			130	0·025
6	Coarse	Medium	Semi-fine	Fine	Superfine			120	From 0·025
7	Very coarse	Coarse	Medium	Semi-fine	Fine			105	
8		Very coarse	Coarse	Medium	Semi-fine	Extra fine		95	to
9			Very coarse	Coarse	Medium	Superfine		85	
10				Very coarse	Coarse	Fine	Extra fine	70	0·045
11					Very coarse	Semi-fine	Superfine	55	From 0·045
12						Medium	Fine	30	
13						Coarse	Semi-fine	25	
14						Very coarse	Medium	20	to
15							Coarse	15	
16							Very coarse	10	0·075

19. *Skin Wool.*—There is another sort of wool not hitherto mentioned, known as "skin wool." This is wool which is taken off the skins of sheep that have been killed, or have died from disease or other causes. It is not clipped off the skin, as is done when sheep are shorn, but the skin is rubbed with lime and water, or with acid, and the roots of the wool are thus loosened. The wool is then pulled out by the roots, and the skin left entirely free. Sometimes, in the case of certain breeds of one year-old sheep, the wool thus pulled off adheres so much together that it retains the form of the fleece, and it is then called "fliped wool"; but usually it breaks up into smaller portions, and all trace of the shape of the fleece is lost. It comes off full of lime, and the sorter is often covered and annoyed with dust, which gets into his throat, and causes much irritation. To lessen the annoyance, sorters' boards are always made of wooden spars with spaces between, or wire gratings, through which much of the dust falls. But in the worst

classes of wool this is not enough, and the dust, if allowed free course, occasionally causes blood-poisoning, and the death of the unfortunate sorter.

TECHNICAL EDUCATION:

IN THE UNITED KINGDOM.—II.

[*Continued from p.* 69.]

BY PROFESSOR W. RIPPER,
Technical School, Sheffield.

ELEMENTARY SCHOOLS.

COMMENCING with the elementary schools, where the basis of all subsequent teaching is laid, great efforts have been made during the past few years, especially by school boards in the large centres of industry, to introduce a more thorough and systematic course of science instruction for the upper standard children. For this purpose highly qualified science teachers have been engaged to visit the schools of a district in rotation, and to give lectures on subjects of science having some practical bearing on the needs of the children. In boys' schools the subject of mechanics or chemistry is more commonly chosen, and in girls' schools domestic economy, each being specific subjects of the Code.

In order to make these subjects interesting and real to the children, and at the same time to develop their intelligence, every opportunity is taken to illustrate the lectures by experiments with simple but effective apparatus, prepared beforehand and carried by the lecturer from school to school. This peripatetic system of science teaching, the success of which was at first considered somewhat doubtful, has proved most effective, and there is now no doubt but that this method of instruction solves the difficult problem of providing sound scientific instruction to large numbers of children at a minimum of cost.

Drawing in Elementary Schools.—In the report of the Royal Commission on Technical Education there was nothing more striking than the evident importance attached to drawing in the educational systems of both France and Belgium, and the very thorough and enthusiastic way in which this instruction was carried on from the primary schools to the advanced municipal art schools. All this was in painful contrast to the drawing instruction given in this country. In 1886 drawing was taught to not more than one-eighth of the scholars in our elementary schools, and the standard of requirements was by no means creditable to a manufacturing nation. Considerable improvement has been made since that date. By the Code of 1890 drawing is now compulsory in boys' schools, and the drawing requirements are modified and rendered much more thorough and serviceable as a course of instruction.

Manual Training in Elementary Schools.—The main object of manual instruction is educational, to cultivate a practical intelligence, and to develop the hand, the eye, and the brain concurrently, so that the boy may go forth into life with some power and desire to make himself useful as well as with a quickened intelligence.

"The essence of manual training lies in the *practice*, and not in the *production;* in the *doing*, not in the *thing* done; and any exercise is valuable only in proportion to the demand it makes upon the mind for intelligent thoughtful work."

It is universally admitted that wood is the most suitable material for the purpose, and in consequence manual training has assumed the form chiefly of exercises in wood-working. The course of instruction to be adopted has been the subject of much discussion. The oldest and best known course, and one which has been reduced to an elaborate system, is that of Swedish *slöjd;* but courses on the whole more suitable for English elementary schools are being conducted at various centres, as London, Liverpool, Sheffield, Edinburgh, and Aberdeen, with much success.

Higher Elementary Schools.—The schools included under this title are chiefly those erected by school boards. They are exceptionally well fitted up with chemical laboratories, physical apparatus, manual-training room, etc; and taught by superior teachers.

The subjects taught are usually those of the Science and Art Department as laid down for organised science schools. Girls are taught, in addition to ordinary school subjects, cookery and domestic economy.

The schools of science and art and the classes connected with the City and Guilds of London Institute, for the most part carried on in the evening, have already been referred to, we shall therefore next consider the work of technical schools.

TECHNICAL SCHOOLS.

As a typical example of an English provincial technical school may be mentioned the Merchant Venturers' School at Bristol.

The erection of the new buildings and the purchase of fittings and apparatus involved an outlay of £45,000. For this sum, says the head master, writing to the *Record* (the journal of the National Association for Promoting Technical and Secondary Education), "buildings have been provided which in themselves constitute an object lesson in construction. The school contains a great hall for popular lectures, examinations, etc., to

accommodate 900 students; nine ordinary class-rooms, a large chemical lecture theatre for 108 students, a smaller chemical theatre, a physical lecture theatre for 108, an engineering lecture room for 56, an engineering-drawing room for 48, two chemical laboratories for 50 at a time, a balance room, combustion room, gas analysis room, physical, metallurgical, and biological laboratories, boot and shoe workshop, metal workshop, carpenters' work-shop, forge, plumbers' workshop, two art-rooms, dressmaking and millinery room, library, engine-house, etc. Each department is fitted out with the latest appliances for teaching and practical work."

Departments.—There are three distinct branches of the institution: (*a*) the boys' school, (*b*) the upper technical school, (*c*) the evening school.

(*a*) The boys' school is for boys from 12 to 16 years of age, and it is divided into a commercial side and an applied science side. Fees from £5 to £6 10s. per year.

(*b*) The upper technical school is for day students over 15 years of age, and is divided into the following sections: mechanical engineering, electrical engineering, chemical and metallurgical, applied art, and building trades. The inclusive fee is £10 10s. a year.

(*c*) The evening school is intended mainly for artisan and commercial students. The list of subjects is a very large one, and covers science, art, technology, and commercial subjects.

The annual cost of the school to the Society of Merchant Venturers is about £1,900.

In addition to the schools of the type described above, there are schools providing courses similar in all respects to that given at the Bristol Merchant Venturers' School, but to which is added one or more departments specially equipped to meet the needs of a leading local industry.

As an example of this type may be mentioned the Sheffield Technical School, in which extensive provision is made for the study of the metallurgy of steel.

The work of this institution is divided into three departments:—

1. The Junior Day Department.
2. The Senior Day Department.
3. The Evening Department.

The junior department is an "organised science school" of the Science and Art Department for boys from 13 to 15 years of age. The senior department provides advanced courses of instruction for students of 15 years of age and upwards, who have already been through the junior department, or who have received an equivalent education elsewhere.

The special courses of study include—

(*a*) The metallurgy of steel and iron.

(*b*) Mechanical, mining, and electrical engineering.

The course of instruction extends over three years in either of these branches, and the fees range from 16 to 18 guineas per year. The training given in this institution combines theoretical instruction with workshop and laboratory instruction of a very practical kind.

The two departments of metallurgy and engineering taken together constitute a most complete arrangement: first, for the manufacture of the various grades and qualities of iron and steel, and secondly, for the thorough testing and working of the materials which are passed on from the foundries to the machine shops.

Other institutions of a similar kind where a specialty is made of instruction bearing directly upon the local industries are to be found at Huddersfield, Bradford, Manchester, Leeds, and elsewhere.

Huddersfield being one of the centres of the woollen industry, a specialty is made of the textile department, where practical and theoretical instruction is given in weaving and pattern designing, cotton spinning, cloth manufacture, and dyeing.

At the Bradford Technical College the weaving department is well equipped with hand and power looms, chiefly for the wool and worsted trade. There are also important chemical and dyeing laboratories in which valuable original research work of a technical character is carried on by advanced students.

Finsbury Technical College.—This institution was established and is carried on by the City and Guilds of London Institute. The work of the college includes—

(1) A day school for students who are taking courses of technical instruction for one, two, or three years.

(2) Evening classes for artisans, apprentices, and others.

There are five departments in the day school, including mechanical, electrical, chemical, building trades, and applied art departments.

The institution is worked entirely independently of the Science and Art Department, and is exceedingly well equipped with experimental appliances, especially for electrical work. The work of each of the above departments is open for evening students, and the classes have a crowded attendance. Beside the ordinary class work, a feature is made of providing short courses of lectures on special technical subjects.

In Scotland, technical colleges of a similar character include the Glasgow and West of Scotland Technical College; Heriot-Watt College, Edinburgh; Technical Institute, Dundee; and Gordon's College, Aberdeen.

The City and Guilds of London Central Institution.—This institution was founded by the City and Guilds of London, and opened in 1885 as a technical university with the principal object of training technical teachers, and also for the technical education and training of those who are preparing themselves to take leading positions in important branches of manufacture. It is believed that this institution will provide similar advantages for higher technical training to those offered in the famous technical universities on the Continent. The total cost, including fitting, machinery, and apparatus, has been £135,000. The departments of instruction include (1) Engineering, (2) Applied Physics, (3) Mathematics, (4) Industrial Chemistry; and they are superintended by professors of the highest reputation in their respective branches of study. The fee for the complete course of instruction is £30 per annum. There are several entrance scholarships tenable for either two or three years. The building and its equipment is in every respect worthy of its high position as the leading technical institution of the country. In the engineering department the equipment includes a fine compound experimental engine and boilers, a 100-ton testing machine, besides a number of other machines and appliances for workshop instruction and experimental research.

The physical laboratories are elaborately fitted up with appliances for instruction in the technical applications of electricity and for carrying on various kinds of research work.

UNIVERSITY COLLEGES.

In addition to the practical science departments attached to the older universities, the University Colleges have been doing an excellent work, though not primarily of a technical character. The chief aim of these colleges is to provide for the higher education of localities which shall reach, as far as possible, university standards. The curriculum, however, has necessarily included scientific instruction, and of late years most colleges have gone so far as to provide, not only for the practical study of chemistry and physics in well-equipped laboratories, but they have added departments of mechanical and electrical engineering with suitable workshop and laboratory appliances.

The principal University Colleges are (1) Owen's College, Manchester; Yorkshire College, Leeds; University College, Liverpool, which together make up Victoria University. (2) University College and King's College, London. (3) University College, Nottingham; University College, Bristol; Durham College of Science, Newcastle-on-Tyne; Mason College, Birmingham; Firth College, Sheffield. (4) The University Colleges of Aberystwyth, Bangor, and Cardiff; and in Scotland (5) University College, Dundee.

As a typical example, we may describe in detail a course of instruction as provided at the Yorkshire College, Leeds. This college provides a course of higher education in preparation for the various degrees of Victoria University. The principal technical subjects of the college include civil and mechanical engineering, coal mining, textile industries, dyeing, as well as modern languages, art, and shorthand. These subjects are in addition to the usual courses of mathematics, physics, chemistry, classics, and literature. The courses of instruction in engineering extend over three years, and comprise lectures on engineering principles and practice, instruction in technical drawing, demonstrations and practice in the engineering laboratory, and visits to engineering works.

The work of the classes, it is said, is not intended in any way to supersede the usual requirements of pupilage or apprenticeship in engineering, but to enable the learner to gain such a knowledge of the principles of his profession or trade as he cannot acquire by simply working in the office, in the field, or in the workshop. The engineering laboratory is furnished with a great variety of appliances for experimental work, including a 100-ton testing machine, and an experimental engine and boiler, besides a good equipment of workshop machine tools.

The textile industries of this college are endowed by the Clothworkers' Company of the City of London, and the course includes lectures and instructions and practical weaving on small hand-looms.

Each student is furnished with a small hand-loom, on which he makes experiments, and weaves the designs furnished in the lectures. Experiments are also made in simple and complex pattern composition.

The cloth finishing room of the department is fully equipped with modern machinery. The dyeing department is also endowed by the Clothworkers' Company, and is said to be the best equipped in England; the course extends over three years, and includes lecture and laboratory work with practical work in the dyehouse and in the printing department.

THE WORK OF THE COUNTY COUNCILS.

After the passing of the Local Taxation Act the county and borough councils suddenly found themselves in possession of a large sum of money, with the power to spend it on behalf of technical education in their respective districts.

Although the subject was such a new one, much steady progress was soon made, and local authorities, while showing a natural amount of caution in expending the large funds at their disposal, have shown praiseworthy anxiety to carry the advantages of technical instruction not only to the large towns but to the villages and remote country districts.

As a typical example of the work of the county councils we may refer to the report of the *Oxfordshire* Committee. The report begins by considering the industrial position and needs of the county and the way in which it may be divided into districts, and it was decided to take as the unit the county council electoral divisions, or some multiple of those divisions, except in the case of the larger municipal boroughs. It was further decided to group the divisions of the county into eight districts, each with a district committee giving a general superintendence to the work carried out in that area; the organising secretary of the county to be ex-officio member of each district committee. The work of the district committees is to ascertain the wants of the various sections of the population, to stimulate public interest, to secure rooms and local assistance, and generally to promote the formation of classes in their district, the efficient working of scholarship schemes, and the distribution of grants of money.

After a careful inquiry as to the nature of the local industries of the county and of the existing means of providing instruction, a scheme was drawn up to include (1) agriculture, both elementary and higher instruction, dairy-work, farriery, poultry keeping, allotment gardening, bee keeping, sheep shearing, thatching, and fruit-growing; (2) secondary and technical schools; (3) scholarships; (4) cookery and domestic sciences; (5) science and art classes and manual instruction.

Agriculture—Elementary Classes.—The aim is to arrange that such instruction shall be as widely spread as possible, so as to reach the out-of-the-way villages as well as market towns and centres of population. A scheme is at work for the training of a limited number of elementary teachers at Oxford as a centre, where they may attend during the summer vacation a three weeks' course of instruction. Those teachers who make satisfactory progress to be encouraged by payment of fees and travelling expenses to continue their training.

Higher Agricultural Instruction.—The following arrangements are proposed:—(*a*) The establishment of agricultural sides in connection with rural secondary schools, and of scholarships leading up to such schools from the elementary schools; (*b*) the provision of evening lectures on agricultural sciences from various centres in the county which should be of value to farmers, to sons of labourers, and others who have passed through the elementary agricultural classes in the village evening school.

Dairy Work.—It is proposed that eventually a central dairy school should be established, probably by grouping several counties together for the purpose. In the meantime it is proposed to establish (*a*) a travelling school for butter and soft cheese-making; (*b*) single lectures or demonstrations on butter-making in the villages; (*c*) scholarships to cheese school at Bath and West of England Society or British Dairy Farmers' Institute at Aylesbury.

Other Branches of Agricultural Instruction.—The chief difficulties in providing instruction in these subjects are (1) to secure a competent teacher; (2) to secure a large enough class in a country village to make it worth while to pay a lecturer. It is intended to make a limited experiment in the way of lectures on farriery. The Farriers' Company offer to provide competent lecturers. With regard to bee-keeping, the Oxfordshire Bee-keepers' Association have endeavoured for some years to promote bee-keeping by means of travelling experts, lectures, etc.

Secondary and Technical Schools in the County.—It is considered that ultimately there should be at least one first-rate secondary school within each of the eight administrative districts, accessible to boys of the labouring class by means of scholarships. At present it is proposed to aid existing schools by giving grants for fitting up laboratories and workshops, and supplying apparatus, models, etc., and also to pay visiting science teachers.

County Scholarships.—Scholarships are offered to scholars in elementary schools to enable them to continue their education in secondary schools; the scholarship to cover the fees, travelling expenses, and also to provide something towards the maintenance of scholars. For this purpose the county proposes to offer twenty-five scholarships each year tenable for two years, of the annual value of not more than £20.

It is also recommended to give a few exhibitions of £60 a year for two or three years, tenable at some place of higher technical and agricultural education, such as the Agricultural Colleges at Cirencester or Downton, or the Finsbury Technical College, or at the University of Oxford.

Scholarships are also offered for the payment of fares for industrial students to attend evening classes in science and art schools.

Cookery and Domestic Sciences.—It has been found that a great demand exists for such instruction, including laundry work, nursing, etc. It is therefore proposed to appoint travelling teachers to visit the various country districts applying for such instruction.

Science and Art Classes.—It is intended to aid these classes by giving grants for furnishing additional models and apparatus, for building new laboratories for science teaching, and by paying capitation grants on attendance.

It may be well to contrast this scheme of an agricultural district like Oxford with the proposals of the *Lancashire* County Councils, where a large number of educational agencies already exist in the centres of manufacture. Grants for technical instruction are offered as follows:—

(*a*) To classes associated with the Science and Art Department and City and Guilds of London Institute; grants to depend to a great extent on the number of students, and the result of the examinations.

(*b*) To classes for teaching domestic sciences to women.

(*c*) For University extension lectures on subjects covered by the Technical Instruction Acts.

(*d*) To technical schools in county boroughs.

(*e*) To found travelling scholarships to assist attendance at technical schools at a distance.

(*f*) To found scholarships at the Liverpool and Manchester Colleges.

(*g*) To central institutions for the purpose of educating teachers.

That a sum be set aside to provide twenty scholarships not exceeding £60 each to be tenable for a term not exceeding three years at some approved institution.

That a further sum be set apart for providing eighty exhibitions of £15 each, tenable for one year at some approved institution, to be divided among students who show proficiency in science, art, commercial, or agricultural subjects.

From the foregoing brief description it will be evident that a great awakening has taken place in regard to the Technical Education of the country, and the efforts which are now being put forth throughout the kingdom under the new powers conferred upon county and borough councils are bringing about quietly but surely a complete revolution in the educational condition of the people, from the agricultural labourer to the leaders of our manufacturing industries.

PLUMBING.—III.

BY A PRACTICAL PLUMBER.

(*Continued from p.* 73.)

WIPED JOINT MAKING (*continued*).

Making Underhand Joints (Figs. 31, 32).—Whilst you have been preparing your joint, your "mate" should have been getting the metal hot and your "kit" in readiness, so that anything required may be handed to you without delay. When the metal is brought you, dip out a small ladleful, and holding a cloth underneath, nearly touching the joint, so that the heat from the metal may be imparted

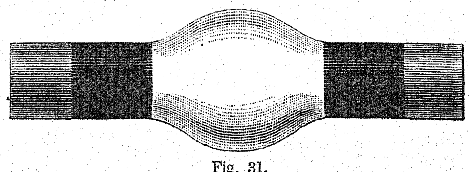


Fig. 31.

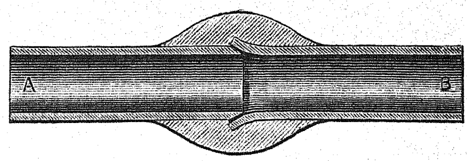


Fig. 32.

to the bottom of the pipe, pour a small dribble of metal on the joint; the shaved parts should be tinned, which is done by rubbing the solder cloth round a time or two with the hot metal in it. Work the solder as you keep pouring from the outsides of the joint towards the centre, and when the pipes are well warm and the solder in plastic and easily-moulded state, wipe round the joint, holding the cloth in a hollow shape, similar to that of a good joint. A good plan to teach beginners the way to hold the cloth in wiping round an underhand joint is to give them a made joint to, as it were, pretend to wipe round—it gets their hand into shape better than you can tell them. The pipes should be kept well hot where the shaving line ends, or the solder will be rough here; this is done by pouring on to the soiled parts. A joint when finished should be symmetrical, not bulgy in one place and squatty in another and full of dents and lumps like a potato; but this desideratum is not reached without considerable practice, and burnt fingers must not be taken into consideration. In using an iron for making the joint, either pour or splash on a sufficiency of solder, and then warm it well all over, and wipe as before. All the operations in wiping should be done as quickly as possible. The saying, "The man who hesitates is lost," certainly applies to wiping joints, for there

must be no hesitation about that, though at the same time there is no necessity to lose one's head over it, as I have seen some do. Never spend a lot of time pouring ladleful after ladleful of solder over a joint, it is waste of time and material, and defeats the object aimed at, viz., a good sound joint, for it causes the heat to extend farther along the pipes than is necessary, so that they take longer to cool down, and the joint has a tendency to become porous by reason of the tin running to the lower part of the joint (*see* "Upright Joint Making"). On small pipes two ladlefuls of solder should be enough, one to get up the heat and the second to form the joint.

Moulded Plumbers' Joints.—Some years ago an affair was brought out, and I believe patented, for making plumbers' joints without wiping. It was a kind of large mould something like a bullet-mould, only open each side to allow the pipes to pass through it. They were made in various sizes, and the *modus operandi* was as follows: the pipes, after the usual preparation (except soiling), were gripped in the mould, which opened like a pair of tongs to receive them, and the solder was then poured in a hole at the top. But it did not find much favour with the plumbers; it certainly made some sort of a joint, but there was no dependence on the soundness of it, and unless care was taken in regulating the heat of the metal, a solid joint was occasionally the result.

Upright Joint Making.—In making upright joints it is necessary, after fitting the joint as described, to fix a collar to catch the solder that drops when splashing on. Fig. 33 shows the pattern for cutting these; several of them should be made of sizes to suit the various pipes—they are much handier than the miserable makeshifts many plumbers use. To make them, take a piece of lead, strike out a circle of sufficient size to allow 3 or 4 inches all round the pipe you are jointing—thus for a 3-inch pipe the collar should be 9 or 10 inches across; the inner circle should be marked a little larger than the pipe. A cut should then be made from the outside to the inner circle and the inner circle cut out; it can then be put on the pipe and the ends lapped over one another; it can be supported by tying a piece of rope round just underneath it. These collars must be well soiled all over to prevent the solder adhering. They should be made and fixed so as to be nearly flat, as the collected solder can be more easily removed. These collars serve a twofold purpose—they

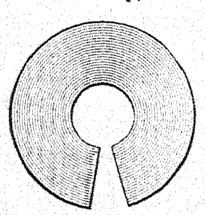


Fig. 33.

keep the solder from falling to the ground and also keep the pipes warm. All this having been properly done, commence making the joint by splashing on the solder (some plumbers can use a ladle for this, but not many). Splash more solder on the upper part than on the lower, and get the metal on as quickly as possible. The iron now comes into play: take it from your mate (who should have it in readiness, well cleaned from scale and dirt), rub well over the solder, form it into shape with the cloth, draw the iron round the upper edge at the back, and wipe. Next perform the same operation at the bottom edge, then change hands and proceed in a similar manner to wipe the front part, and the joint is completed. Remove the collected solder from the collar and put back into the metal pot.

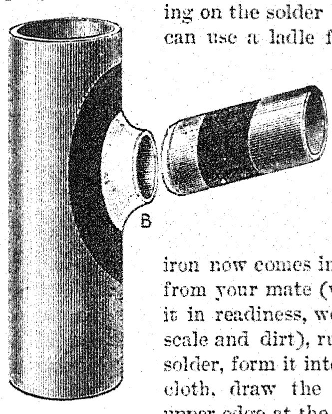


Fig. 34.

The reason of wiping the top part of a joint first is because the solder cools there first; there are two reasons why this is so—one is because the hot solder falling round the lower pipe keeps that warm, and the other reason is that the solder is coarser at the top of a joint than at the bottom owing to the tin having a tendency to fall to the bottom of the mass of solder through its greater fluidity, and therefore the bottom part takes longer to cool.

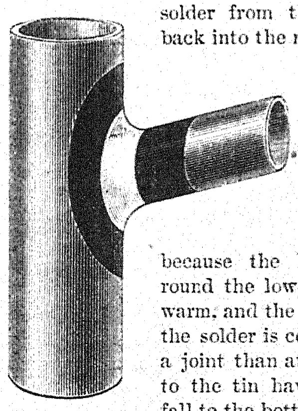


Fig. 35.

Branch Joints (Figs. 34 and 35).—Bore a hole in the main pipe somewhat smaller than the pipe that is to branch into it, and with a tool called a "tommy," or bolt, work up the edges of the hole as shown at Fig. 34 A B. This must not be done by leverage—*i.e.* by pressing one end on the bottom of the pipe and pulling up the "tommy," but by using a hammer. Careless workmen will sometimes simply bore the hole nearly the full size of the pipe, and then rasp down the entering pipe to allow it to slip in a little way, and then make the joint; the difference between the

two modes is easily seen by comparing Fig. 36 and Fig. 37, which show section of branch joint properly and badly fitted. In Fig. 36 there is a clear

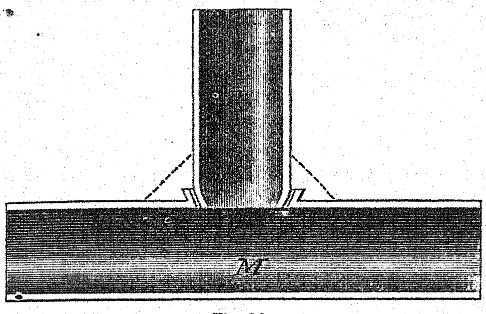


Fig. 36.

way or passage along the pipe M, no obstruction of any kind, while in Fig. 37 the branch pipe projecting through as shown at E E would retard the

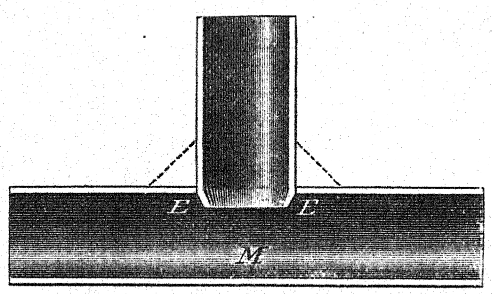


Fig. 37.

flow of any liquid through it in proportion to the amount it projected through. Thus if Fig. 37 was part of a waste pipe from a bath or housemaid's sink, it would catch any particles of hair or rag, and in time a stoppage would be the result.

Shaving and Soiling.—This can be seen at Fig. 34, and should be neatly and cleanly done. (*N.B.*—Always "touch" the shaved parts of lead pipe, etc., as soon as shaved, or they will tarnish rapidly, and the solder will not take nicely.) The wiping, etc., is the same as previously described for underhand joints, except that a smaller-sized cloth is generally used.

Soil Pipe Branches.—These branches should always enter the main pipe at an angle pointing in the direction of the flow of the main pipe.

To fit these, cut the male pipe across to the angle required, then lay it on the pipe that is to be branched into and scribe round it; the mark will be in shape like A B C D, Fig. 38. Bore two holes E E, and cut it along the dotted lines, then dummy up the side of the hole thus formed to fit the branch pipe. Use the utmost care to get a perfectly tight fit all round, or in making the joint the solder might run inside and form icicle-shaped obstructions, which would certainly soon cause a stoppage in the pipe, and call down anything but blessings on the head of the workman (?) who caused it. In

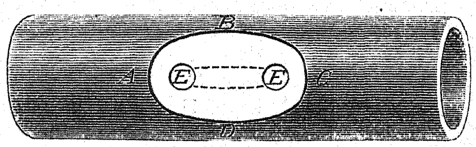


Fig. 38.

wiping branch joints keep the catchboards as close to the work as possible, that the falling solder may keep the pipes warm: it is an advantage also to stop up the ends of pipes whilst soldering to prevent the cold air passing through.

Flange Joint.—Fig. 39 shows a sectional view of the joint known by this term. It is usually employed for small pipes, and is made when passing

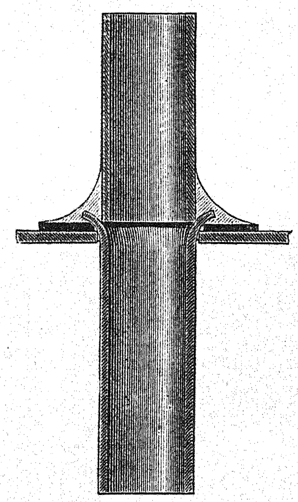


Fig. 39.

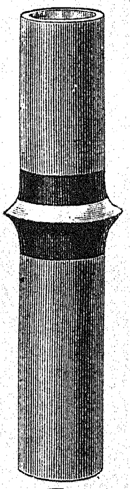


Fig. 40.

through a floor, working upwards. The pipe is left up about an inch through the floor and a lead collar slipped over it; the pipe is then flanged back upon the collar (of course after shaving collar and pipe), and the wiping is an easy matter. Care should be taken in tafting the pipe back not to get it to a sharp angle, as it weakens the pipe and renders it liable to break at the edge of the tafting.

Taft Joint (Fig. 40).—This is the simplest form of wiped joint that the plumber has to make, in fact it is much despised by some, and looked upon as derogatory to a plumber to make one. Whilst

admitting that it is not a very elegant-looking joint and not so strong as a band joint, yet I cannot join in its utter condemnation, and maintain that when well made it is a serviceable and reliable joint. It is simply made: the edge of the lower pipe is thrown back with the turnpin to form a ridge for the solder to rest on, and the upper pipe should enter quite half an inch. The wiping calls for no remark.

Overcasting Joints.—This practice does not obtain to a very great extent in the present day, at any

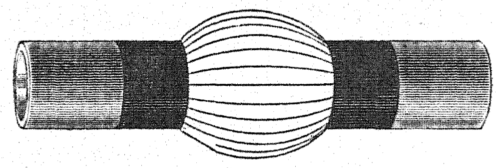


Fig. 41.

rate in England: it is supposed to give joints greater strength. It is done after wiping by drawing the neck of a hot iron lengthwise along the joint, giving it a ribbed or fluted appearance as

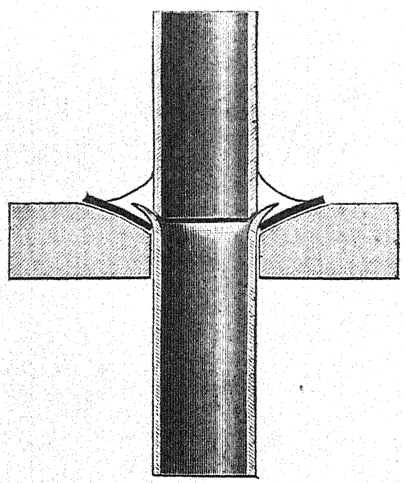


Fig. 42.

shown at Fig. 41. Specimens of this kind of work may frequently be found in pulling out old plumbing work, some neatly done, some quite the reverse.

Block Joints.—These are somewhat similar to the flange joints but stronger, and are used for connecting soil pipe when fixed internally in a chase in a wall. A block of wood is hollowed out as shown in section at Fig. 42. A lead flange is cut about 5 or 6 inches larger in diameter than the pipe, a hole is cut in it the size of the pipe, and then it is worked to the hollow of the block and shaved; some plumbers shave and tin it first, and also the end of the upper pipe, and it is certainly a plan to be recommended. The lower pipe is then tafted out as shown in sketch, so as to allow the solder to run underneath the tafting as well as on top, thus giving a double grip for the solder, and making a very strong and firm joint. In wiping block joints let the solder be nice and hot, so as to ensure it taking at the back part of the joint. Wherever a joint comes in an awkward position, as regards brickwork being in the way, it must be cut away. Never stand for a foot or two of masonry, that can easily be made good. Of course I do not mean that on the least little difficulty as regards space, etc., that brickwork or woodwork should be recklessly cut away, but simply where it seems impossible to make a good job without it, then the convenience of the plumber must be studied.

Joints other than Soldered.—The plumber has frequently to make joints in connecting pipes quite differently from those that have been described. These I think will not be out of place if described here. We will take first—

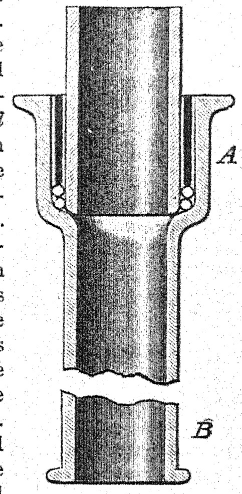


Fig. 43.

The Putty or Red Lead Joint.—This is used in connecting the service pipe from the water supply to the closet pan. There is a nozzle projecting from the closet basin or pan, into which this pipe fits, and it has to be made tight and sound as it has to resist a pressure varying according to the height of the supply. The entering pipe should be quite round and free from rough edges, and both it and the inside of the nozzle should be painted; if this is done a few hours before using it will be all the better; the object of doing this is to afford a key or grip for the cement or putty. Most plumbers use only putty for making this connection, the only advantage this has is that it is cheaper and that it is easier to remove should the pipe ever require to be taken out. A cement made by mixing white and red lead in the proportions of two of white and one of red (by weight) will be found superior to putty. The lead pipe should enter the closet arm about $1\frac{1}{2}$ inch, a portion of cement is then squeezed in between the pipe and the nozzle, and also formed round it in somewhat the same shape as a

wiped joint. A piece of canvas two or three inches wide, painted both sides with some thick red lead paint, is then wound round and round like a bandage, and lastly this is wound round with fine tar cord and fastened tightly and painted again. If possible no water should be let through for 24 hours, but this cannot always be, of course especially in repairing jobs. Care should be taken that the nozzle of the closet pan does not bear any of the weight of the lead pipe. Several patent connections have been invented to do away with this method, and will be spoken of in their place.

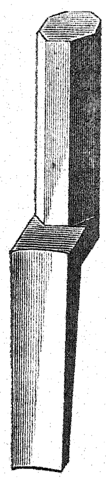


Fig 44.

Lead Caulked Joints. — Fig. 43 shows a section of this kind of joint. It is used for connecting cast-iron gas and water mains, and should always be the form of joint when iron pipes are used for soil pipes. A is termed the socket end and B the spigot end; a couple of rings of gasket, or gaskin as some call it, is first caulked into the joint, it is then filled with molten lead, and when cold caulked tight with a caulking chisel (Fig. 44). When these pipes lie in a horizontal direction, after caulking in the gasket a fillet of clay must be put round the pipe with a small hole at the top for pouring in the lead. Joints in socket pipe are also made with yarn and red lead cement only; this method, however, is not suitable for joints in soil pipe, and should never be adopted. It is the usual method of connecting hot-water pipes. The way to make the joint is to ram tightly a single length of gasket first, then a ring of the red lead cement before mentioned, then a double ring of gasket, another layer of cement, then another double ring of gasket—if the depth of the socket will admit of it, if not, a single ring—and face up with cement. These pipes are also sometimes connected with india-rubber rings in place of the packing just described: this is a very quick method of jointing, but it is not equal in my opinion to the gasket and red lead joint for durability.

Flange Joints. — Another form of connecting wrought- or cast-iron pipes is by means of flanges, which have three or more holes drilled in each; an india-rubber washer is usually the packing employed to make the joint sound, and the flanges are bolted together, forming a very secure and sound joint. Instead of rubber a plaited grummet of tar cord may be employed. In screwing up flange joints of any kind, always screw the nuts equally all round, not one tight first and then another.

STEEL AND IRON.—III.

By William Henry Greenwood,
F.C.S., M.Inst.C.E., M.I.M.E., Assoc. Royal School of Mines.

[*Continued from p. 80.*]

IRON AND STEEL (*continued*).

The several grades of *foundry pig-iron* also present well known characteristics when in the molten state. The fluidity of the molten metal decreases as the grade number rises: thus molten No. 1 pig-iron appears in the founder's ladle to be dark and sluggish, giving off neither sparks nor splashes as it is poured into the moulds; No. 2 presents a brighter red appearance, pours from the ladle in large sheets, splashes a little, and exhibits an ever varying kind of figured appearance as the metal cools in the ladle. In No. 3 the surface figuring of the molten metal is much less distinct, and it throws out sparks rather abundantly during the period of pouring. The scum or *kish*, which rises to the surface and separates most largely in No. 1 and less abundantly in No. 2 iron, occurs much more sparsely in No. 3. No. 4, which is the hardest number usually employed by the founder, throws out showers of sparks during pouring, and the surface of the molten metal as it stands in the ladle always appears hotter than do the previously described lower numbers.

The mechanical and certain physical changes produced upon pig-iron by varying proportions of carbon, in either the graphitic or the combined form, have already been noticed; but other elements besides carbon are constantly present in pig-iron, and these also modify its character and limit its applications to the various purposes of the arts: thus *silicon*, derived from the reduction of silica in the blast furnace, is present in almost all pig-irons in amounts varying in ordinary pigs from 0·1 per cent. to 5 per cent. It is usually stated to exist, in soft grey iron (as smelted with hot blast from refractory ores), both in the combined and the graphitic condition; but the mechanical separation of graphitic silicon from pig-iron has not yet been effected, and the evidence of its existence as such is alike unsatisfactory and imperfect. Owing to the comparatively low working temperature of charcoal furnaces the pig-iron produced therein contains smaller proportions of silicon than occurs when coke is employed as the fuel: the quantity of silicon is further always increased when free *silica*, siliceous ores, or iron sands are charged into the furnace, with an insufficiency of lime to combine with the excess of silica; a siliceous pig is also produced when a light *burden*—that is, a large proportion of fuel to ore—is charged into the furnace; for this reason on first blowing in a furnace, a highly siliceous

iron, known as *glazed* or *blazed* pig-iron, is often produced.

Silicon is very necessary in hæmatite pig-iron intended for use in the acid Bessemer process; but its presence in large quantity diminishes the strength of the pig-iron for foundry purposes, although its presence increases the fluidity of the molten metal, and so is permissible in the pig for the manufacture of fine castings not requiring great strength. In pig-iron for puddling, the presence of silicon diminishes the yield of iron and increases the loss by waste. An excess of silicon renders pig-iron weak and inferior, although in proportions up to about 1·5 per cent. it increases the strength and also the softness with which the metal works under cutting tools: the latter quality probably arising from an increase in the graphitic and a decrease in the combined carbon, which generally attends the introduction of silicon into the pig-iron, or the mixture of a siliceous iron with a pig comparatively low in silicon. Thus, for foundry purposes, a pig-iron containing much combined carbon, but low in silicon, sulphur, phosphorus, and manganese, may be improved by mixing it with a siliceous pig, since such addition tends to the separation of graphitic carbon and the production of a softer metal. Hæmatite pig-iron for conversion into steel by the acid Bessemer or Siemens process usually contains from 2 to 4 per cent. of silicon, which in that case, owing to its high calorific power, is desirable for the successful conduct of the process.

Sulphur is present to the extent of from 0·02 to 0·15 per cent. in the pig-iron smelted from clay ironstones without any admixture of cinder; but in smelting for common forge-pig in South Wales cinder is sometimes added to the furnace charge, and the sulphur then often reaches as much as 0·7 per cent., but pig-iron containing upwards of 0·03 per cent. of sulphur is undesirable for conversion into steel either by the Bessemer or the Siemens process, since it yields a steel which is invariably *red-short;* but for foundry purposes sulphur up to ·03 to ·05 per cent. makes the pig stronger, and hence the practice in Sweden of occasionally adding small quantities of pyrites to the furnace charge when smelting pig-iron for ordnance, shot, etc., the pig-iron thereby produced presenting in fracture a slightly mottled appearance; but pig-iron for general foundry purposes should not contain more than ·1 per cent. of sulphur. White iron usually contains more sulphur than grey iron when made from the same materials.

Phosphorus is a constituent of most pig-irons, its tendency being to increase the hardness and brittleness of the metal, to make the fracture more largely crystalline, and to increase its fluidity when in the molten state. If present to the extent of 1 per cent. or upwards, it reduces the tensile strength of the iron; but it is doubtful whether smaller proportions have any decided influence upon the strength of cast-iron. Pig-iron containing 1 per cent. of phosphorus is well adapted for the manufacture of light castings not requiring great strength. The pig-iron smelted from a heavy burden of cinder sometimes contains as much as 2 per cent. of phosphorus, and often presents a honeycombed structure along the upper surface of the pig, whilst such metal frequently contains also considerable proportions of sulphur. When the blast furnace is working satisfactorily and producing a good grey slag, then the whole of the phosphorus in the ore, fuel, and fluxes is reduced and passes into the pig-iron; whilst if the furnace be running on a dark-coloured basic scouring slag or cinder, rich in iron, then a portion of the phosphorus passes out in an oxidised state into the slags. Pig-iron containing more than about ·04 per cent. of phosphorus is undesirable for conversion into steel except by the basic process, which latter requires a metal containing 1·5 per cent. or upwards of phosphorus, while hæmatite pig rarely contains more than ·1 per cent., and more usually only from ·03 to ·05 per cent. of phosphorus.

Manganese is present in most pig-iron, for like phosphorus, the manganese of the iron ore is found after smelting to be partly in the blast furnace slag and partly in the pig-iron. The tendency of manganese is to render pig-iron white, hard, brittle, and stronger under crushing stresses; while its presence in iron ores promotes the elimination of sulphur from the pig-iron smelted therefrom. Manganese is desirable in pig-iron for puddling or for conversion into steel; and its presence appears to increase the power of the pig to occlude hydrogen, but decreases this power with respect to carbon monoxide. Manganese should not exceed ·5 per cent. in foundry iron for the production of strong castings.

Spiegeleisen is a highly manganiferous pig-iron, containing from 6 to 20 or 30 per cent. of manganese, and usually possessing well-marked physical qualities: thus it is very hard, and its fracture often presents large cleavage planes or lamellar crystals; but spiegeleisen and highly manganiferous iron may also present a granular crystalline fracture void of any cleavage or lamellar structure.

Ferromanganese is a still more manganiferous pig-iron, containing from 50 to 85 per cent. of manganese, an increasing demand for which has arisen in connection with the production of very

mild, soft, weldable steel; as also for use in the manufacture of other manganiferous alloys.

Traces of *copper* and *titanium* appear to occur in all grey pig-irons, but cupriferous pig-iron is unfit for conversion into malleable iron or steel, since copper renders these latter "red-short." Titanium appears to yield a stronger iron. *Tin* makes pig-iron hard and more fusible, but the malleable iron prepared from stanniferous pig is cold-short and inferior.

The pig-irons of the several smelting districts of Britain often present distinguishing characteristics. Thus the *Cumberland hæmatites* are generally less siliceous than those of Lancashire. *Cleveland iron* is characterised by a high percentage of phosphorus, and is rarely very siliceous. *Scotch pig* made from Blackband ironstone is similar to Cleveland iron, but contains probably a little less phosphorus, and is so ranked as a little superior to the latter. *Lincolnshire* and *Northamptonshire* irons are similar, but the first named contains less phosphorus and also less silicon than the Northampton pig-iron. The furnaces of *Bowling* and *Farnley* yield a strong iron, which is used also for conversion into the highest classes of malleable iron.

ORES OF IRON.

In some form or other, iron is the most universally diffused of the metals, but minerals like the sulphides, phosphates, titanates, and silicates of iron, although containing large proportions of iron and occurring in considerable abundance, are not suitable for smelting purposes, and the workable iron-ores belong to a very small class of minerals, which differ, however, rather considerably both as to their yield of iron and in the nature of the gangue or foreign matters which accompany the iron-yielding mineral.

Ore is the name applied to the metalliferous matter in the state in which it is extracted from the mine by the miner, and in the case of iron the ore is always either an *oxide* or *carbonate of the metal*, accompanied by certain extraneous matters, *gangue*, or *vein stuff*, essentially either *siliceous*, *calcareous*, *argillaceous*, or *bituminous* in character. In Wales and some other districts the term "mine" is used as synonymous with ore, the same word being thus used to designate both the workings and the metalliferous matter extracted from them.

Upon the nature and quantity of the foreign matters associated with the pure mineral, the practicability, or otherwise, of profitably working a deposit of iron ore depends. Thus a hæmatite iron ore, though rich in iron, if associated with any considerable proportion of ferrous sulphide (iron pyrites), would be thereby much reduced in value, or probably be valueless; whilst 5, 10, or 15 per cent. of manganese in spathic ores, or of carbonaceous (bituminous) matters in a clay ironstone, increases the value of such ore.

Iron ores occur distributed throughout rocks of almost all ages, but the most abundant deposits are found in the Silurian, Devonian, and Carboniferous rocks, although brown hæmatites also occur largely on the Continent and in the colonies in Liassic and Oolitic rocks, as also in the Wealden and Lower Greensands. The United Kingdom in the extent and variety of its workable ores of iron will bear favourable comparison with any other part of the world. Of iron-yielding minerals, as already stated, the *sulphides* and *silicates* of iron occur very abundantly, but are not available as ores of iron. *Native* and *meteoric irons*, again, are of such rare occurrence, irregular distribution, and small weight as to exclude them from being considered as sources of iron for industrial purposes. Of the *oxides of iron* used in iron-smelting, the most important are the *magnetites* and the *red* and *brown hæmatites*, whilst the *carbonates* embrace the *spathic iron ores*, and the *argillaceous carbonates* known as *clay ironstones*.

Magnetic Iron Ore or "*Magnetite*" is the richest and one of the most widely distributed of the ores of iron; it occurs in irregular beds, sometimes of considerable thickness, but not usually of great extent, in various parts of Norway, Sweden, the Ourals, Siberia, Elba, the United States, and Canada. The composition of magnetite is represented by the formula Fe_3O_4, but the ore usually contains only from 80 to 90 per cent. of the magnetic oxide of iron, accompanied with from 5 to 15 per cent. of silica. The Swedish magnetites are also practically free from sulphur and phosphorus, whilst some contain considerable proportions of manganese. The pure mineral is iron-black or iron-grey in colour, gives a black streak, is brittle, magnetic, and sometimes distinctly polar; it is generally found in the massive form, yielding a crystalline or granular fracture; but it is also found in the form of grains or as a black sand. It is from these ores (magnetites) smelted with charcoal that much of the famed Dannemora (Swedish) iron is obtained. The ore as employed at Dannemora yields on the average less than 50 per cent. of metallic iron, and is accompanied by a gangue, containing silica and lime, in sufficient quantities to permit of the mineral being smelted without the addition of any further flux to the furnace charge.

Franklinite, which closely resembles magnetite, but is less magnetic, occurs in the limestones of New Jersey, in the United States, and is there first treated for the extraction of zinc, while the

residues so obtained are afterwards smelted for spiegeleisen. Franklinite consists of *ferric* and *manganic* oxides $(FeMn)_3O_4$ with *ferrous, manganous*, and *zincic* oxide (FeMnZn)O, and it contains an average of about 45 per cent. of iron, 9·5 per cent. of manganese, 20·50 per cent. of zinc.

Titaniferous Iron Ore, or *Ilmenite*, occurs massive, but it is found more generally as a dark-coloured or black sand along the shores of the Bay of Naples, the north-east coast of America, Labrador, New Zealand, etc. In these districts certain ferruginous rocks disintegrate, and whilst the lighter clay is washed away, the heavier metalliferous particles, or grains, accumulate upon the shore as iron-sands, which, after a preliminary mechanical treatment, can be smelted in the American Bloomery Furnace for the production of wrought-iron direct from the ore. The sands contain a large proportion of magnetite, along with titaniferous iron ore, free silica, and more or less magnesia. Titaniferous iron ore is a most refractory mineral, which has been used with some success as a lining material for revolving puddling and other furnaces; the sands are difficult to treat in the blast furnace, but the smelting of bricks made of these sands with calcareous clay and carbonaceous matters is a partial success.

Red Hæmatite is the name applied to a most important class of iron ores, which consist essentially of anhydrous ferric oxide (Fe_2O_3), and which vary in colour from deep red to steel-grey, with a crystalline, fibrous, columnar, botryoidal, or amorphous structure. From the variety of their physical characters the red hæmatites have received special names: thus, a crystalline variety of a bluish or steel-grey colour, which occurs at Elba, Brazil, etc., is known to the mineralogist as *specular iron*, or *iron-glance*; it contains, when pure, 70 per cent. of metallic iron. The scaly, micaceous, or foliated variety, which is used as the basis of a paint for ironwork, is known as *micaceous iron ore;* the dull, hard, compact masses, often reniform (kidney-shaped) such as occur in Cumberland, are known as *kidney ore.* The soft and more earthy varieties constitute *red ochre*, whilst *puddler's mine* or *ore* is the soft, unctuous, compact, earthy form, known also as *smitty ore*, which is employed for the making and repair of the bottoms of puddling furnaces; and lastly as small, hard, flattened grains it is recognised as *lenticular clay iron ore.* Red hæmatite is often associated with the brown oxides, and the ore is further classed as *hard* or *soft*, according as it contains free silica in excess or otherwise, and the hard ore is also known as *blast ore.*

Hæmatite iron ores, owing to their comparative freedom from sulphur and phosphorus, and to the large proportion of silicon contained in the pig-iron smelted from them, have been in large demand for use in the acid Bessemer process for the manufacture of steel. Until the discovery of the "*basic process*" of Bessemer conversion, only hæmatite pig-iron was suitable for the process. The most important deposits of red hæmatite are found in the Cambrian, Silurian, Devonian, and Carboniferous rocks; the deposits of North Lancashire, Cumberland, and Flintshire occurring in veins and irregular masses in the mountain limestones of the Carboniferous series. The more important Continental and foreign deposits of these ores occur in Sweden, Norway, South Germany, Canada, and the United States. In the North Lonsdale district the ores yield from 40 to 62 per cent. of iron, or an average from 52 to 54 per cent. of metallic iron, the other ingredients being 4 to 5 per cent. of silica, with lime, magnesia, aluminia, and earthy matters.

Brown Hæmatite, or *Brown Iron Ore*, is when pure a hydrated ferric oxide, represented by the formula $2Fe_2O_3 3OH_2$, and would thus yield 59·89 per cent. of metallic iron; but the ore, which varies from blackish- to yellowish-brown in colour and differs much in composition, will often yield in its undried state only from 50 per cent. to 64 per cent. of ferric oxide (Fe_2O_3) with very variable proportions of sulphur and phosphorus. Brown hæmatite occurs in irregular, compact, more or less homogeneous masses, in the Carboniferous limestone and lower Coal Measures of the Forest of Dean, Gloucestershire, and Glamorganshire; whilst a less pure variety, containing more or less mechanically mixed sand, occurs in the Lias, the Oolites, and Lower Greensands of Northamptonshire, Lincolnshire, Buckinghamshire, and Oxfordshire. Brown hæmatites also form one of the most important of the ores smelted in France and Germany.

The Spanish mines of Somorrostro, near Bilbao, yield a brown hæmatite, which has probably been deposited from hot springs charged with ferrous carbonate $(FeCO_3)$, and throughout the hæmatite are often found blocks of unaltered spathic ore. It is estimated that at these mines 70,000,000 tons of ore are in sight.

"*Bog Iron Ore*" is an impure brown hæmatite, smelted in Canada principally for foundry purposes. *Limonite*, again, is another form, as are also the so-called "*lake ores*," which occur in granular concretionary masses, dredged during the winter months from the bottom of certain shallow lakes of Norway, Sweden, and Finland. The mineral known as "*göthite*" is a crystallised and rich variety of brown hæmatite, and an earthy variety containing much clayey matter constitutes "*yellow ochre.*"

Spathic Iron Ores, Siderite, Clay Ironstones, Blackband and *Cleveland Ironstone* are the names given to certain ores of iron, in which the metal occurs as a ferrous carbonate ($FeCO_3$) of greater or less purity, and from which ores nearly two-thirds of the total weight of the pig-iron produced in Great Britain is smelted.

Spathic Ore in its purest form constitutes the crystallised mineral known as "*siderite*," which, when pure, yields 48·27 per cent. of metallic iron. Siderite has a pearly lustre, and varies from yellow to brown in colour, but when exposed to water and atmospheric influences, it usually suffers decomposition, and becomes converted into brown hæmatite to a considerable depth from the surface. Spathic ores often vary much in composition, but manganous oxide is almost invariably present, in some cases to the extent of 50 per cent. or upwards; lime and magnesia, as also iron and copper pyrites, are frequently present in sensible proportions, so that the manganiferous pig-iron (spiegeleisen) produced from these ores often contains small quantities of copper. Spathic carbonates of iron occur in England in the Carboniferous limestone of Durham, Cornwall, and the Brendon Hills in Somersetshire; on the Continent these ores occur abundantly, as in the Siegen district of Prussia, in Styria and Westphalia, and to a smaller extent in Carinthia. This ore has been in considerable demand for the production of spiegeleisen.

Clay Ironstone is the argillaceous, amorphous, compact, earthy or clay-like variety of ferrous carbonate, which occurs either in detached nodules, or in layers of nodular concretions, distributed through the shales and clays of the Coal Measures, and in beds of considerable thickness in Liassic rocks. When not discoloured by admixture with coaly or carbonaceous matters or by atmospheric decomposition, it ranges in colour from light grey or yellow to brown, but the lighter-coloured varieties rapidly become brown on exposure to the atmosphere. Like siderite, it contains besides ferrous carbonate appreciable quantities of calcium, magnesium, and manganese carbonates, along with clay (aluminous silicate), phosphoric anhydride, iron pyrites (FeS_2) and occasionally also other minerals, like blende (ZnS) and galena (PbS). The principal localities of its occurrence are the clays and shales of the Coal Measures of North and South Staffordshire, Derbyshire, Yorkshire, Warwickshire, Shropshire, North and South Wales, Denbighshire, and in Scotland, while the coal-fields of Northumberland, Durham, and Lancashire are almost void of this mineral. About 20 per cent. of the British make of pig-iron is obtained from clay ironstones.

COTTON SPINNING.—III.

BY HENRY RIDDELL, M.E.

[*Continued from p.* 77.]

PRELIMINARY MANUFACTURING OPERATIONS.

THE preceding section of these lessons dealt in some detail with the cotton plant, its cultivation, varieties, and the character of the fibre produced therefrom. The present section is intended to treat of the preliminary manufacturing operations, including the ginning, mixing, opening, and lapping. It will be necessary also to make some remarks upon the subject of cotton buying, and glance at the question of baling and storing.

Ginning.—The operation of removing the seeds from their enveloping fibre is called "ginning," and the machines used in the process are known as "gins." This process is here treated among manufacturing operations, since it is now mainly executed in buildings set apart for this purpose alone, whose owners receive the cotton from the surrounding plantations, and are paid according to the quantity of fibre passed through the machines. The machinery employed has become more delicate in adjustment, and skilled labour is now absolutely required if the enormously increased producing power is to be properly utilised.

The seed, when removed from the cotton, was formerly used for fuel, but like many other by-products has now become an exceedingly valuable portion of the out-turn. It is pressed, and the oil thus obtained is largely used upon its own merits, as well as for an adulterant for olive oil, and also for lard; while the resultant oil cake is worked up into a feeding material.

In earlier times ginning was treated as an agricultural operation solely, and executed by means of very primitive appliances, and at an expenditure for labour out of all proportion to the value of the fibre obtained. The problem to be solved in successfully removing the seeds from the cotton is by no means a simple one, as a little consideration will show. The seeds are not lying loose among the fibres, but are the bases from which the fibres grow and to which they are firmly attached; and those seeds must be removed without any unnecessary tearing of the fibres or crushing the seed, as such crushing would seriously injure the cleanliness as well as the appearance of the cotton.

The machine formerly used for ginning purposes, and indeed still in limited use, consisted of two small wooden or metal rollers, driven by foot-treadle or hand-wheel, and geared in such a way as to permit of adjusting their distances apart. For the purpose of preventing the seeds from passing between the rollers with the fibre, the rollers

were made very small in diameter, not much exceeding half an inch, and set apart a distance considerably less than the smallest diameter of the seed.

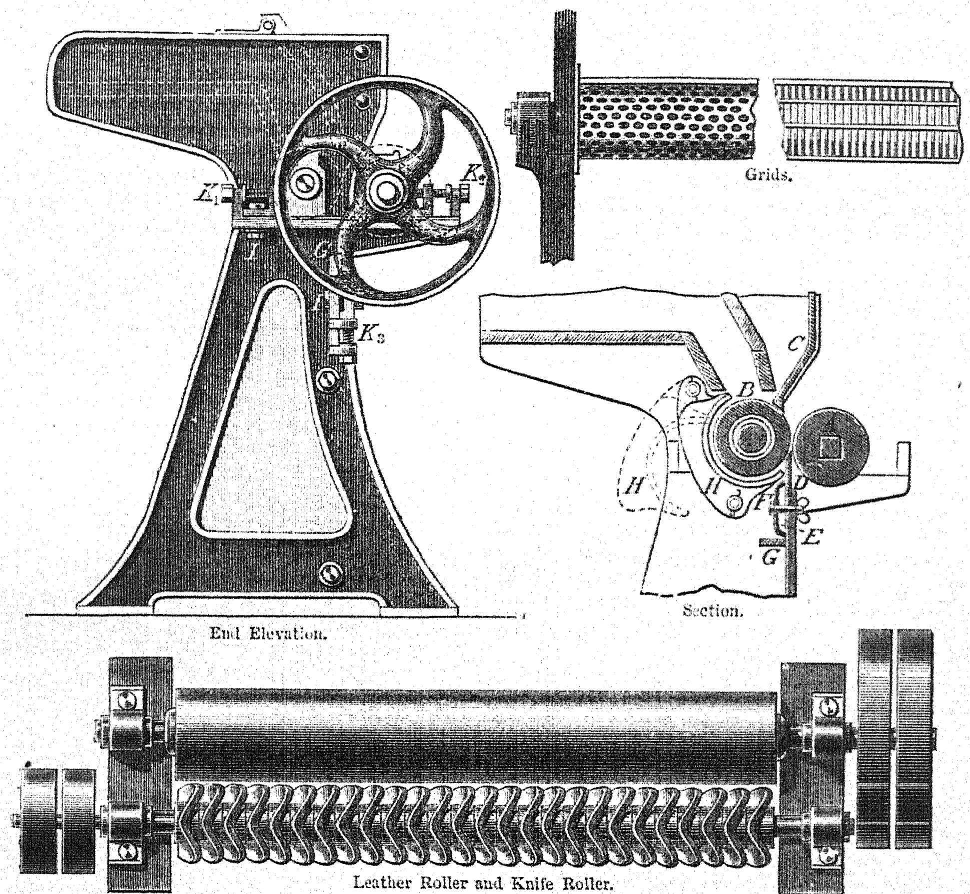


Fig. 6.—KNIFE ROLLER GIN.

They were deeply grooved lengthwise to enable them the easier to seize upon the fibre. The production from a machine of this class was miserably small, averaging only about 30 lb. to 40 lb. of cleaned fibre per day, comparing most unfavourably with the 1,000 lb. to 2,000 lb. per day turned out from the most modern development of the machine.

The machines at present in use belong to two classes; one of which, the roller machine class, has been evolved from the rude inefficient contrivance above described, while the other is a departure on fresh lines, and is known as the "Saw Gin." There are many machines included in these two varieties, but as they resemble each other greatly in their principles, three only will be described.

Roller Gins.—The most universally adopted of the roller gins has, perhaps, been that known as the "Macarthy," from the name of its inventor.

This consists essentially of a roller and two knives, one knife blade being fixed as a "doctor" upon the roller, while the other is given a rapid oscillating motion by means of a crank driven from the roller shaft. The roller is constructed generally of wood and covered with walrus leather, the surface being deeply grooved spirally to assist in laying hold upon the fibres. The cotton being seized by the roller is drawn beneath the fixed blade, where the seeds are unable to pass as the knife fits closely to the roller. At the same time, a short distance in front of the intake beneath the

fixed knife, the oscillating blade is rapidly moving, pushing, and forcibly separating the seeds from the fibre, so that the latter passes beneath the "doctor-" like blade freed, and is either cast direct upon the ground or removed in any convenient way.

The most efficient, however, of the many varieties of the roller machine is that manufactured by Dobson and Barlow, and known as the "double action knife roller" machine.

This machine is shown in Fig. 6, and its action may be understood from the following description.

The leather roller A is, like that of the "Macarthy Gin," covered with walrus leather, grooved lengthwise with a slight twist spirally. These grooves allow of the roller seizing the cotton fibres to draw them past the doctor knife D in a manner already described. The great departure in the construction of the machine is in the application of the knife roller B with an action partly as a feed and partly as a cleaner and stripper of seed. The cotton is fed into the trough, whence it falls directly upon the knife roller B, and, owing to the construction of the latter, is carried forward beneath the guard C, which is set sufficiently close to B to prevent an excessive quantity of the fibre reaching the leather roller. Having at length reached the roller A, the cotton is caught by the grooves and slight roughness of the leather and carried past the steel doctor knife D. This knife has its edge pressed tightly by means of the springs F against the surface of A at about the level of its centre or a little below, so that no seeds can possibly follow the fibre through the slight space allowed by the yielding of the springs. The knife roller B is perfectly parallel to A and distant from it about the diameter of a seed, while it is set perfectly clear of the doctor knife. Thus the cotton drops in a continuous web from the leather roller, on the front side of D, while, stripped by the action of the blades of B, the seeds are carried past the edge of D into the trough-shaped grid H, the perforations in which vary according to the cotton, and thence drop to the ground.

The adjustments provided in this machine are the following. By means of the screws K_1 K_2 the bearings carrying both B and A have independently an adjustment of approach or recess, while the height of the edge of D and its pressure on A are capable of alteration by means of the screws K_3 and E. The screw K_3 acts directly upon the cross bearer upon which D rests, while E acts through the spring F, thus providing a yielding pressure upon the leather roller. The knife roller B requires some attention, as upon it depends the rapid working of the machine, owing to the quick freeing of the seeds by the action of its blades. This roller is constructed in its simplest form of a number of discs mounted upon a shaft and set obliquely, as shown in the drawing in the plan of the two rollers. The gearing of the two rollers A and B is independent, and it will be readily understood that by the blades of B during its rotation the seeds are rapidly pressed from side to side as well as downward, the amount of to and fro movement being governed by the angle of inclination of the blades.

This machine, when skilfully worked, is capable of stripping and delivering in good condition a very large quantity of fibre varying from 2,000 lb. of Egyptian to 700 lb. of Dharwar, the out-turn being greatly affected by the nature of the cotton.

Saw Gins.—The most generally esteemed ginning machines adopted by cotton growing and cleaning

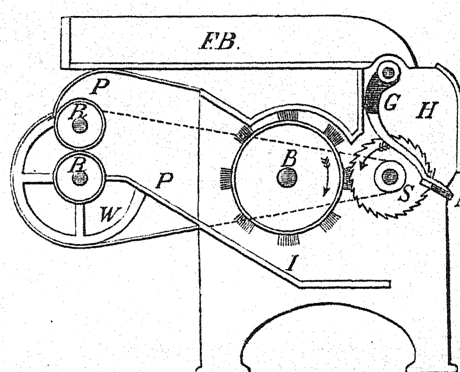


Fig. 7.—Saw Gin.

establishments in America belong to the second great class, known as "saw gins." In Figs. 7 and 8 are presented sectional and perspective views of machines of this class; by means of these the working of the gins will be easily understood. Fig. 7 is a diagram of the sectional details of a machine of English manufacture, chosen because of its simplicity, while Fig. 8 shows a very well-known and highly popular machine, constructed in America by the Eagle Machine Company. It will be perceived that a feeding arrangement is present in this case, but the action of the cleaning machinery will be seen by the section of the simpler tool shown in Fig. 7.

The essential parts of this machine are the saw roller S, the grid G, brush B, rollers R R, and the perforated plates P P. These perforations allow the escape of the air currents caused by the brush, and thus help to direct the cotton where it is desired. The saw-roller S, which is constructed by stringing a number of steel circular saws upon one spindle, setting them apart by means of washers sufficiently thick to allow the thin bars of the grid G to pass

between them. These bars are so close to each other as to prevent the seeds from passing, while the fibre seized by the teeth of the saws is rapidly stripped from them by the brush B, which revolves at high speed in the direction shown by the arrow.

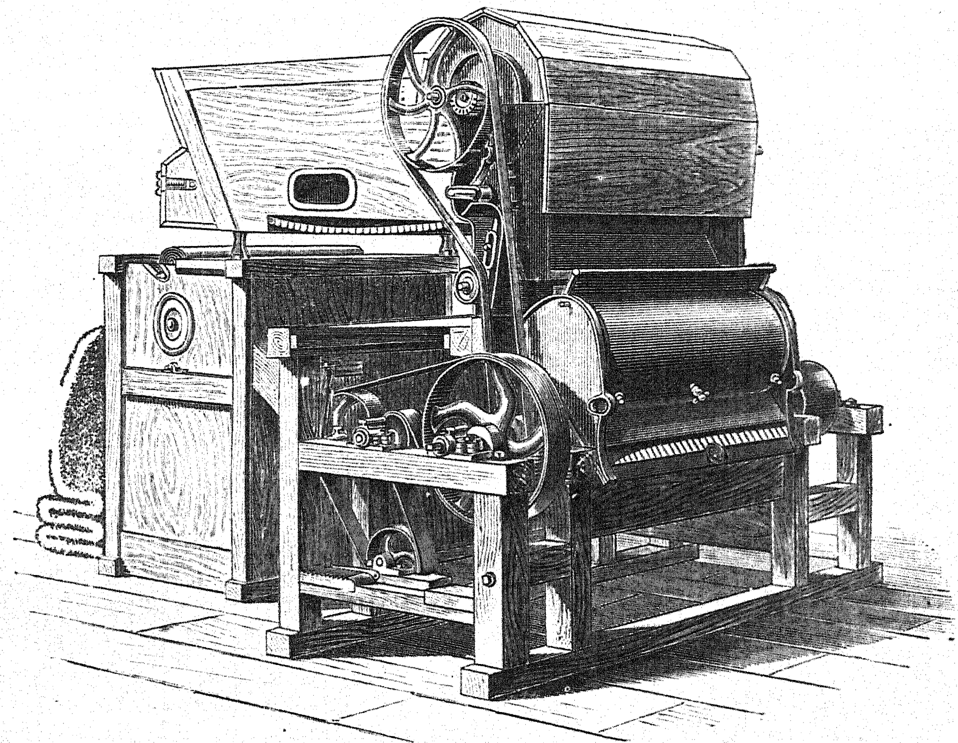


Fig. 8.—Eagle Cotton Gin.

The cotton is thrown by the revolution of the brush, and the air motion thus caused, upon the incline marked I and over the interior of the box, especially upon the perforated plates P P and the rollers R R, also perforated. The cotton in a fleecy condition has sufficient cohesion to be removed from the plates and incline by means of the rollers, and is delivered in a web outside the machine. The saws are driven as shown, and the brush B is driven sometimes directly and sometimes by the same belt as the saws. The seeds from which the fibres have been drawn by the saws drop through M upon the ground.

For short-fibred cottons the "Eagle Gin," shown in perspective, has been very successful, but in the long-stapled varieties the "Dobson and Barlow" is to be preferred.

Ginning is usually an operation but indifferently performed, the amount of seed and leaf allowed to pass in fragments being very large, sometimes reaching 10 per cent. of the delivery. This is perhaps largely to be attributed to the factory system of ginning, causing it to be to the interest of the proprietors to press through the largest possible quantity of seed cotton, even at a sacrifice of those qualities which are such future helps to the spinner.

Baling.—Like the ginning, the baling of cotton is carried on in works unconnected with the growers. The merchant-house dealing in cotton purchases from all the plantations in its neighbourhood, and after sorting the fibre, bales it, marking each bale according to the estimate formed of its quality.

Owing to the necessity of reducing its bulk to allow of its economical transportation over long distances, cotton is very heavily compressed. This pressure is applied by a great variety of presses, screw and hydraulic, and is certainly injurious to the fibre, not so much by the pressure it is subjected to as by the additional work required to properly open the cotton before carding it.

The bales are bound by steel hoops so constructed as to be easily fastened, this fastening being only drawn tighter by the expansion of the bale on being released from the press. The weight of the bale varies according to the locality; thus American averages about 480 lb., Egyptian (heavily compressed), weighs 720 lb., Smyrna and Indian 400 lb. Syrian 320 lb., while the Brazilian and Peruvian cotton is packed in light parcels of about 170 lb. to 220 lb.

It is essential to the success of the future manufacturing processes that each bale should contain only one quality and variety of cotton, and neglect or unskilfulness in the sorting at this point leads to great waste and injury to the yarn at a future stage. There are four main divisions of quality in cotton, known as Ordinary, Middling, Fair, and Good. Each of these is subdivided into about three or four more minute classifications according to English custom. The final classification of quality is effected by reference to certain standard samples, adopted by the cotton trade, and changed at intervals, as the new crop may be found better or worse than the old. A few of such subdivisions are "Ordinary," "Good Ordinary," "Lower Middling," "Fair Middling," "Middling Fair," "Fair Fair," "Good Fair," "Good," "Fair Good," and "Very Good."

These classifications are not all employed for cotton of any one kind, the grading differing according to the growth; for instance, American cottons are classed from "Good Ordinary" to "Middling Fair," Pernams from "Middling Fair" to "Good Fair," Indian cottons from "Fair" to "Very Good," and Egyptian from "Fair" to "Good." Hence in the table given of prices and characteristics the prices are for the best class of Americans and the lowest grade of Egyptian or Indian cottons. This requires to be borne in mind when considering the comparative commercial values of the fibres.

As showing the effect of these classifications upon prices, the following short table may be examined. It represents prices current in July, 1892, in pence per lb. in Liverpool.

	Middle.	G. M.	M. Fair.	Fair.	G. Fair.	Good.	V. Good.
American . .	$4\frac{1}{16}$	$4\frac{1}{4}$	$4\frac{1}{2}$	...	...	...	...
Pernams. . .	...	...	$3\frac{15}{16}$	$4\frac{5}{16}$	$4\frac{9}{16}$	...	...
Maranhams .	...	...	$4\frac{1}{16}$	$4\frac{1}{4}$	$4\frac{1}{2}$	...	...
White Egyptn.	...	...	...	$4\frac{1}{2}$	$4\frac{5}{8}$	5	...
Brown ,,	...	...	...	$4\frac{9}{16}$	$4\frac{13}{16}$	$5\frac{1}{8}$	...
Broach . . .	..	...	...	...	...	$3\frac{5}{8}$	4
Dhollerah . .	...	...	...	$2\frac{15}{16}$	$3\frac{3}{16}$	$3\frac{7}{16}$	$3\frac{3}{4}$
Bengal . . .	...	...	...	$2\frac{5}{8}$	$2\frac{13}{16}$	$3\frac{1}{8}$	$3\frac{1}{2}$
Tinnevelly .	...	...	...	$3\frac{1}{2}$	$3\frac{11}{16}$	4	...

PROJECTION.—III.

[*Continued from p. 84.*]

CHANGE OF POSITION OF THE CO-ORDINATE PLANE.

THE student has already seen that two projections are necessary to determine the position and shape of a body in space.

Now *any* two projections—provided they both be complete enough—are *sufficient* to determine a body in space. For example, Fig. 29 may represent either a square prism resting with one long face on the ground and another pair of faces parallel to the V.P., or a right cylinder lying on the ground with its axis horizontal and parallel to the V.P.

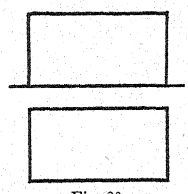


Fig. 29.

Fig. 29 gives plan and elevation of all the edges of the prism; it also gives plan and elevation of the circular bases; and of the curved outline of the cylinder.

Fig. 30 shows the same plan and elevation lettered, and by a little careful study it will be seen that it now represents a square prism.

Fig. 31 shows the same plan and elevation, but

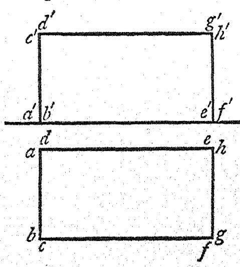


Fig. 30.

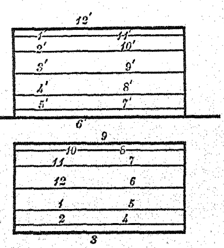


Fig. 31.

with the addition of plans and elevation of 12 lines lying on the surface parallel to the axis of the solid. The addition of these lines removes all ambiguity as to the solid represented, which can only be a right cylinder.

Now if we took another elevation looking in the direction of the axis, the shape of the solids in Figs. 30 and 31 would be seen at once. We therefore have to study the problem of drawing a third projection of a solid, having given two. Since our drawing of plans and elevations of solids reduces ultimately to drawing plans and elevations of points, we will first study the problem with regard to a single point.

Let P, Fig. 32, be a point in space, and p and p' its plan and elevation on the co-ordinate planes whose line of intersection is X Y. Take another

plane $V_1 V_1$ at right angles to the plane H H and intersecting it in the line $X_1 Y_1$. The projection of P on this plane is p'_1. If the plane V V be rotated about X Y, and the plane $V_1 V_1$ about $X_1 Y_1$ into the

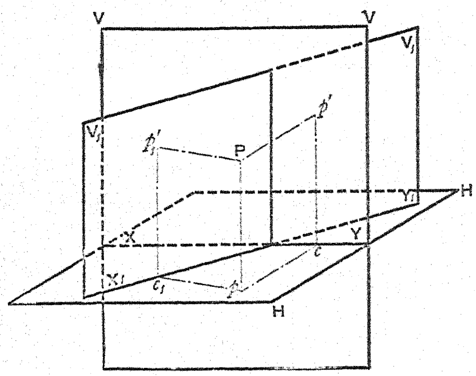


Fig. 32.

horizontal plane, carrying with them all points projected on them, the projections of P will appear as in Fig. 33. Now in Fig. 32 evidently $c\,p' = c_1 p'_1$, therefore also in Fig. 33, $c_1 p'_1 = c\,p'$. Hence the following rule: To find a new elevation of a point having given one plan and elevation, draw from the given plan a projector perpendicular to the new X Y, set off along this projector above the new X Y a distance equal to the height of the old elevation, above the old X Y. Compare $c\,p'$ and $c_1 p'_1$ in Fig. 33.

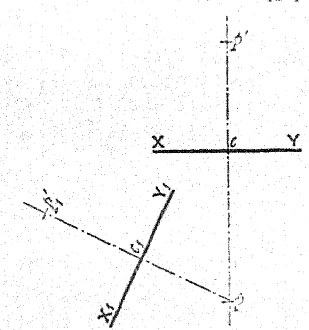


Fig. 33.

And remembering that the V.P. and H.P. are *co-ordinate* planes—that is, what is true with regard to one is true with regard to the other—we get the following problem and solution.

Problem.—Given plan and elevation of a point, find a new plan. Draw from the given elevation a projector perpendicular to the new X Y. Set off along this projector below the new X Y a distance = distance of the given plan from the old X Y. Fig. 34 shows the point in space, and the planes of projection in their relative positions; Fig. 35, the plans and elevation corresponding.

Problem.—Given plan and elevation of a solid to draw a new plan or elevation.

Exercise 1.—Take the solid given in Fig. 22 and let a new elevation be required on an X Y, making 30° with the long edges on the plan.

From the points a, b, c . . . . in the plan (Fig. 36) draw projectors perpendicular to $X_1 Y_1$, and

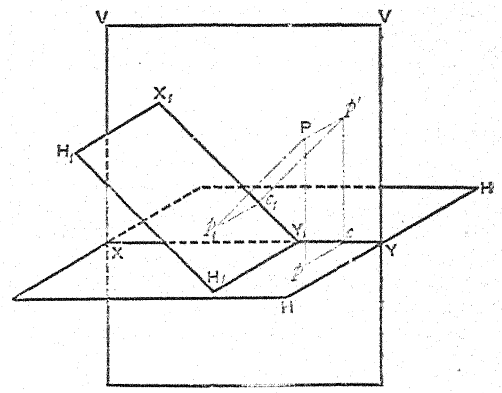


Fig. 34.

mark off the points a', b', c' . . . . along these projectors the same distances respectively from $X_1 Y_1$ as a', b', c' are from the old X Y.

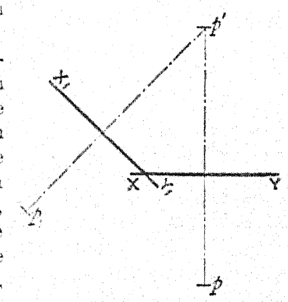


Fig. 35.

For the new elevation all lines which are hidden when the solid is viewed in the direction of the arrow are drawn dotted. For example, A E is right at the back, and therefore $a'_1 e'_1$ will be dotted, and similarly for the lines $e'_1 f'_1$ and $e'_1 h'_1$.

Exercise 2.—From the new elevation in Exercise 1 draw a new plan, the new ground line being inclined 45° to $X_1 Y_1$. From a'_1 draw a projector at right angles to $X_2 Y_2$, and set off $c_2 a_2$ from $X_2 Y_2$ equal to $c_1 a$. a_2 is the new plan of the point A. A similar construction must be employed for the other points of the solid. The working out is left as an exercise for the student.

Exercises 3, 4, 5.—Draw new plans of the solids in Figs. 23, 25, 26, the new ground lines being inclined 45° to the old.

The working out of the pyramid and octahedron presents no new feature.

In the case of the cone, Fig. 26, there are no angular points in its base, but a number of points are chosen arbitrarily in the base and these points are projected in the usual way. In Fig. 37, 12 points are taken in the circumference of the circle which forms the base, their elevations

1′, 2′, 3′, ... are drawn, and from them projectors perpendicular to the new ground line $X_1 Y_1$ are drawn.

The new plans 1_1, 2_1, ... of the 12 points

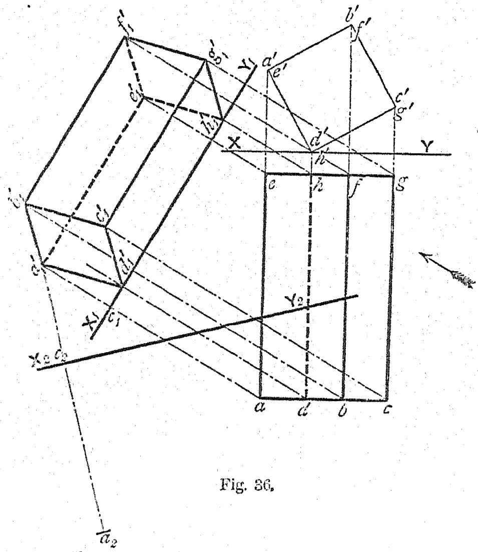


Fig. 36.

are at the same distance from $X_1 Y_1$ as the old plans 1, 2, 3 . . . . from X Y.

Through 1_1, 2_1, 3_1, ... a curve must be drawn freehand.

From v_1, the new plan of the vertex, two tangents are drawn to this curve, so completing the outline of the new plan.

Exercises 6, 7, 8.—From the new plans in Exercises 3, 4, 5 draw new elevations on ground lines inclined 30° to $X_1 Y_1$.

These exercises call for no special remarks. Exercise 8 is shown drawn out in Fig. 37.

We are sometimes asked to draw a solid in a certain definite position, which necessitates the drawing of the preliminary plan or elevation in a particular way. In all such cases the arrangement of the first plan and elevation and the new ground line must be carefully thought out—if necessary, with the help of models—before beginning the drawing.

The following rules will be of service. If a solid is to be drawn with one line, having a given inclination to the $\frac{\text{vertical}}{\text{horizontal}}$ plane, the first plan and elevation should be drawn so that the $\frac{\text{elevation}}{\text{plan}}$ of the given line is parallel to X Y.

If a solid is to be drawn, with one plane face having a given inclination to the $\frac{\text{vertical}}{\text{horizontal}}$ plane, the first plan and elevation should be drawn so that the $\frac{\text{plan}}{\text{elevation}}$ of the given face is represented by one straight line.

If a solid is to be drawn with one line or face parallel to the $\frac{\text{vertical}}{\text{horizontal}}$ trace, the $\frac{\text{plan}}{\text{elevation}}$ of the given line or face may be drawn, if possible, parallel to the X Y.

The case in which the inclination of a face, and also the inclination of a line, is given, is more complicated, and will be treated later on.

Exercise 9.—Draw plan and elevation of a hexagonal pyramid when one of its long edges is inclined 30° to the H.P. According to first rule, the first plan must be drawn having the plan of a long edge parallel to X Y (Fig. 39). The new ground line $X_1 Y_1$ must be drawn at 30° to $v' a'$. The rest of the drawing is as in the former exercises.

Exercises 10 and 11.—Draw plan and elevation of

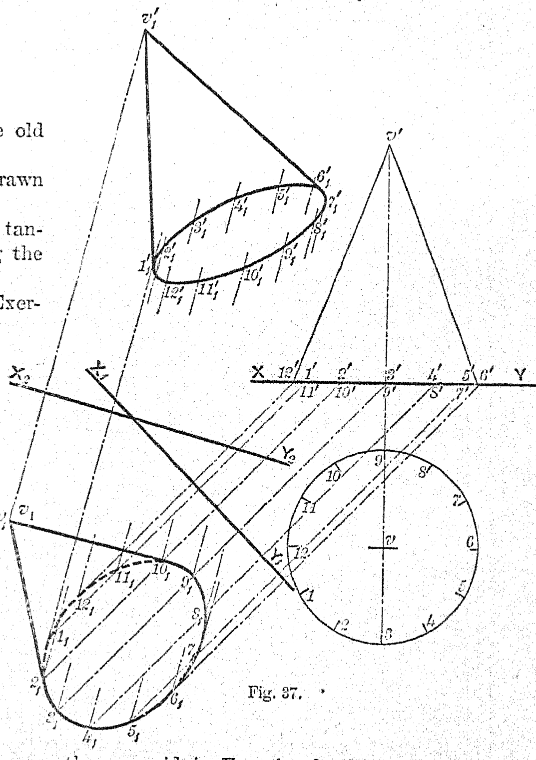


Fig. 37.

the pyramid in Exercise 9 when a long edge is (10) vertical, (11) horizontal. The first plan and elevation will be the same as in Exercise 9, but the new ground lines will be $X_2 Y_2$ and $X_3 Y_3$,

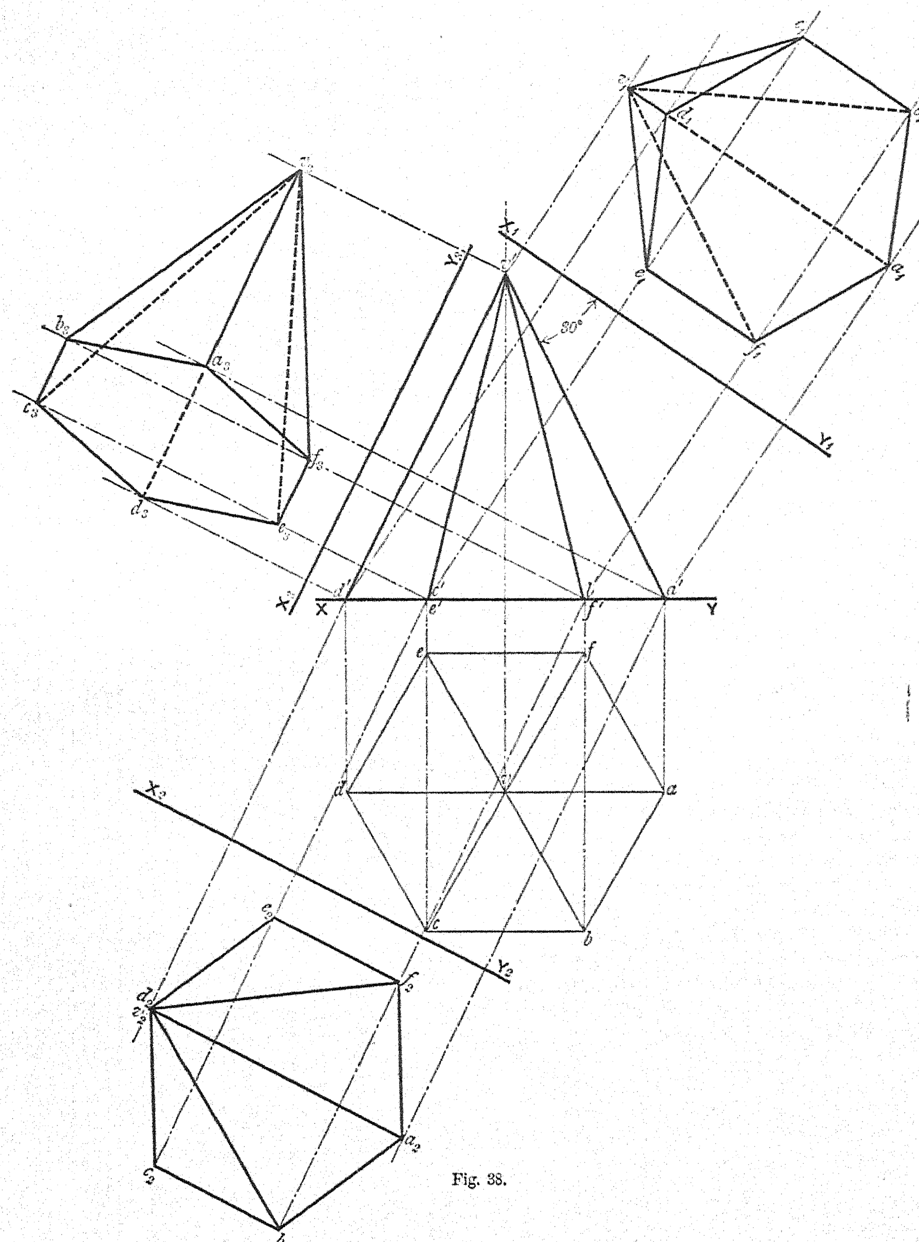


Fig. 38.

perpendicular and parallel respectively to $v' d'$ (Fig. 38).

Exercise 12.—Draw an octahedron 2″ edge when one face is inclined 30° to the H.P.

By the second rule, the elevation of one face should be a straight line. Look at Fig. 25, and we see that if the plan be drawn with $b\,c$ perpendicular to X Y, the points b' and c' in the elevation will coincide.

In Fig. 39 the new $X_1 Y_1$ is taken inclined 30° to $b' f'$.

Exercise 13.—Same octahedron as in Exercise

12, but with one face resting on the ground. The new ground line X_2Y_2 coincides with $b'f'$

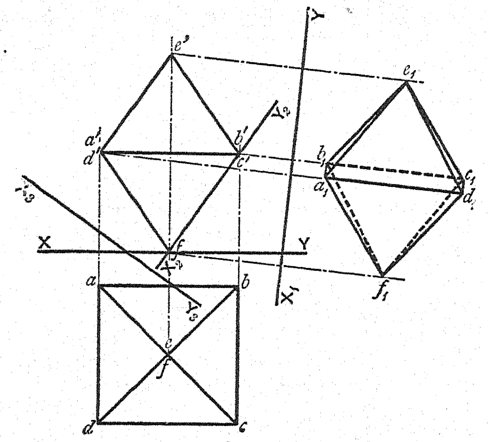


Fig. 39.

(Fig. 39). The outline of new plan is a regular hexagon.

Exercise 14.—Same octahedron, but with face vertical.

The new ground line X_3Y_3 (Fig. 39) is at right angles to $b'f'$.

Exercise 15.—Draw plan and elevation of a cube

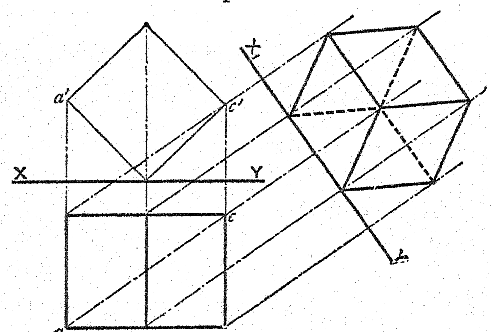


Fig. 40

$1\frac{1}{2}''$ edge when a diagonal is at right angles to the V.P. By the first rule, the first plan and elevation must be drawn so that the elevation $a'c'$ of a diagonal is parallel to XY (Fig. 40). X_1Y_1 is taken at right angles to ac, the plan of the diagonal.

The outline of the new elevation is a regular hexagon.

Exercise 16.—Draw plan and elevation of a cone, 3″ diameter of base, and 4″ high, when lying with one of its generating lines on the ground. The new XY is taken coinciding with $v'b'$ (Fig. 26). Fig. 41 shows the drawing complete.

Exercise 17.—A cylinder, 3″ diameter and 4″ long, has its axis horizontal and its bases inclined

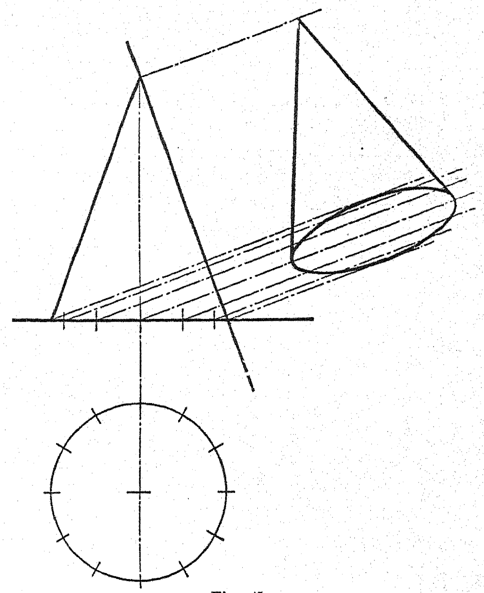


Fig. 41

30° to the V.P. Draw plan and elevation. Fig. 42 shows the solution: the student should have no

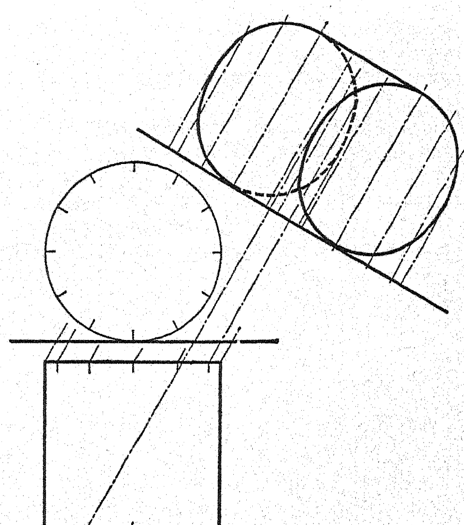


Fig. 42.

difficulty in tracing the steps in the construction.

THE STEAM ENGINE.—III.

By Archibald Sharp, B.Sc., Wh.Sc., A.M.I.C.E.,

Instructor in Engineering Design at the Central Institution of the City and Guilds of London Institute.

[*Continued from p.* 109.]

EXPANSION OF GASES (*continued*).

Adiabatic Expansion.—If a gas expands or is compressed without receiving or losing heat, the expansion or compression is called adiabatic.

Let A (Fig. 24) represent the initial state of the gas—that is, its volume is O a and pressure a A.

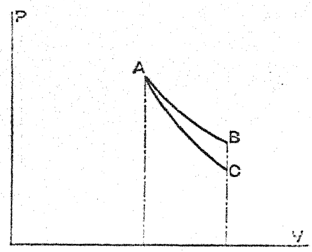


Fig. 24.

Draw an isothermal line A B through A and let B be a point on this isothermal. Since the gas in expanding from A to B receives heat, if it expands without receiving heat to the same volume, its pressure must be less. Thus the adiabatic A c drawn through A must lie nearer the axis O V than the isothermal. In other words the adiabatics are steeper than the isothermals. It can also be shown that any adiabatic intersects *all* the isothermals.

Heat Absorbed in Isothermal Expansion. Latent Heat of Expansion.—We have already seen that when a gas expands isothermally, it must receive heat, although its temperature remains unchanged. In Fig. 25 let air expand isothermally from state A to state B. Through A and B draw two adiabatics,

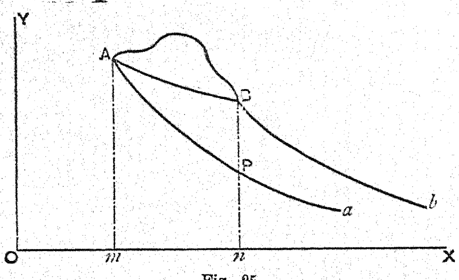


Fig. 25.

A a and B b. Now if the adiabatic A a be produced far enough, it will cut the isothermal for a temperature a fraction of a degree above absolute zero, or in the limit we may say it cuts the isothermal T $=0$ at an infinite distance from the origin O. But when the temperature of a gas is absolute zero it possesses no heat. The air in expanding adiabatically from the state A does an amount of external work represented by the area X m A a included between the ordinate m A, the axis of volume m X, and the adiabatic A a. If the expansion be carried out till the temperature is zero, the energy left in the gas is zero, and all the energy which was in the gas in state A must be equal to the work done in expanding indefinitely, *i.e.* = area X m A a.

Similarly the energy in the gas when in state B is represented by the area X n B b.

Since the temperatures of the gas in the states A and B are the same, the internal energy—that is, the quantity of heat sensible as temperature—in state A is the same as in state B. Therefore

Area X m A a = area X n B b.

Now in expanding from A to B the gas absorbs heat, and also loses an amount of energy equal to the external work of expansion. Hence

Energy in state A + heat absorbed during expansion—external work of expansion = energy in state B.

That is—

Area X m A a + heat absorbed during expansion —area m A B n = area X n B b,

∴ Heat absorbed during expansion = area X n B b + area m A B n − area X m A a = area a A B b.

That is, the heat in foot-pounds absorbed during isothermal expansion is equal to the area included by the isothermal and the adiabatics, produced to infinity, passing through the points representing the initial and final states.

We have above

Area X m A a = area X n B b.

Add to each side of this equation the area A P B, then area X m A B P a = area X n P A B b.

Take away the common area X n P a, then area m A B n = area a A B b.

That is, the heat absorbed during isothermal expansion is the mechanical equivalent of the external work done during expansion.

If the difference of volumes of states A and B be unit volume, the quantity of heat absorbed is called the latent heat of expansion.

During adiabatic expansion the heat absorbed is by definition zero. Let a gas expand along any path A C B (Fig. 26); take a number of points $p_1 p_2$ . . . . close together on the path A B, and through them draw isothermals and adiabatics, the adjacent curves intersecting in q_1, q_2 . . . . Suppose now the path of expansion to be A $q_1 p_1 q_2 p_2 p_3$ . . . . , the heat absorbed will be the area a A q_1 $p_1 q_2 p_2$ p_3 . . . . B b. If the points p_1 p_2 be taken infinitely close, the path A q_1 p_1 q_2 . . . . B becomes the

same as A C B, and thus ultimately the heat absorbed during expansion along any path A C B is the area included by the path and the two adiabatics through the initial and final positions.

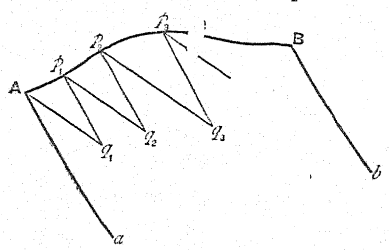


Fig. 26.

The specific heat of a solid or liquid has been defined as the quantity of heat necessary to raise the temperature of unit mass one degree. But with gases it is necessary to specify the relation existing between pressure and volume while the temperature is being altered. Two cases are important.

Specific Heat at Constant Pressure is the amount of heat requisite to raise the temperature of unit mass of the gas one degree while the pressure remains constant. Let the pressure and volume of the gas at temperature t be represented by A (Fig. 27). Through A draw the isothermal for the temperature t, and draw also the isothermal for temperature $t+1$. Then if the temperature be gradually raised

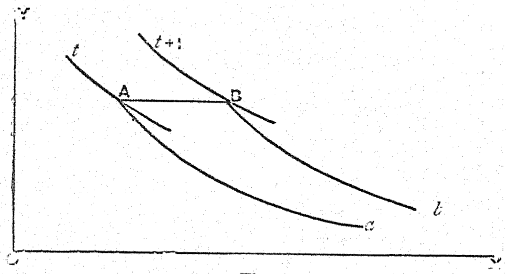


Fig. 27.

one degree while the pressure remains constant, the path of expansion of the gas A B_1 is parallel to O X, and B lies on the isothermal $t+1$. Through A and B draw adiabatics. Then the specific heat of the gas at constant pressure—in foot-pounds—is equal to the area a A B b, and will be denoted by the symbol c_p. For air $c_p = \cdot 2375$ thermal unit $= 184{\cdot}7$ foot-pounds.

Specific Heat at Constant Volume.—In Fig. 28 let the two consecutive isothermals t and $(t+1)$ be drawn. If the temperature be raised 1° while the volume of the gas is kept constant, the "path of the gas" will be A B parallel to the axis of pressure O Y; A and B lying on the isothermals t and $t+1$ respectively. Through A and B draw the adiabatics A a and B b. The specific heat of the gas at constant volume in foot-pounds is equal to the area a A B b, and will be denoted by the symbol c_v. For air $c_v = \cdot 1686$ thermal unit $= 131{\cdot}2$ foot-pounds.

In a perfect gas if the volume be kept constant all the heat applied is "sensible," and therefore

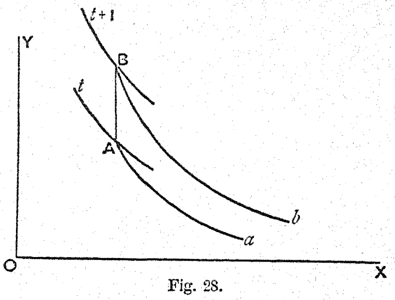


Fig. 28.

the specific heat at constant volume is the same for all temperatures. That is, the heat required to raise the temperature of a perfect gas from 32° F. to 33° F. is the same as is required to raise it from 300° to 301° F. whatever be the volume occupied, provided the volume is kept constant during the application of heat. Thus in Fig. 22, if A and B be points on two consecutive isothermals, A and B representing the same volume, and if adiabatics A a and B b be drawn, the area a A B b will be the same in whatever part of the diagram A and B are taken.

Expressions for the Heat Absorbed in Expansion

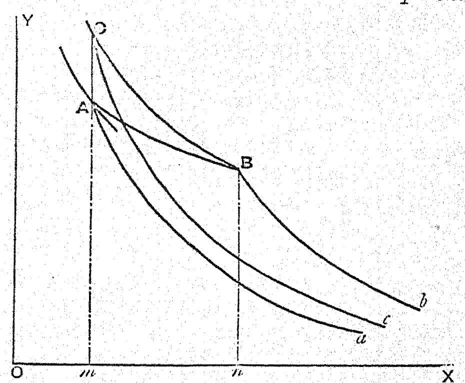


Fig. 29.

by any Path.—Let A and B (Fig. 29) be two points very close together on the path of expansion. Draw isothermals through A and B. From A draw a line parallel to O Y to meet the isothermal from B in C. Through A, B, and C draw adiabatics A a, B b, and C c respectively. Let Δt be the difference

of temperatures of states A and B, and let ΔH be the heat absorbed in expansion from A to B;

$$\text{Then } \Delta H = \text{area } aABb$$
$$= aACc + cCBb - ACB;$$
$$\text{But area } cCBb = \text{area } mCBn,$$
$$\therefore cCBb - ACB = mCBn - ACB = mABn,$$
$$\therefore \Delta H = aACc + mABn.$$

Now $aACc$ is the heat spent in raising the temperature of the gas Δt at constant volume, and is therefore equal to $C_v \Delta t$. $mABn$ is the external

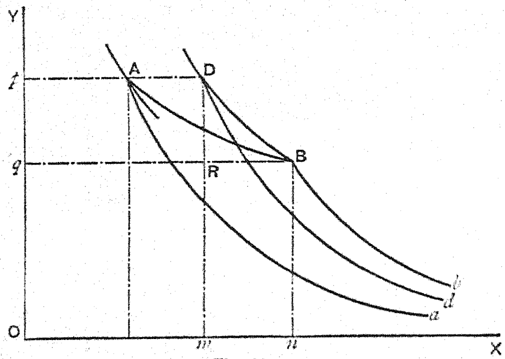


Fig. 30.

work done by the gas during expansion, and if Δv be the difference of volumes represented by A and B, and p be the mean pressure during expansion, it may be written $p\Delta v$.

Finally, therefore,

$$\Delta H = C_v \Delta t + p \Delta v \text{ .... (1).}$$

Another expression for ΔH can be obtained. In Fig. 30 from A draw a parallel to OX to meet the isothermal through B in D. Draw adiabatics Aa, Bb, and Dd through A, B, and D. Draw ordinates Dm, Bn, and draw Ap and Bq parallel to OX to meet the axis OY. Let Dm and Bq intersect in R. Then by the same reasoning as before—

$$\Delta H = \text{area } aABb$$
$$= aADd + dDBb - ADB$$
$$= aADd + mRBn + DRB - ADB.$$

Since the equation to the isothermal DB is $pv =$ constant, the rectangle qn is equal to the rectangle pm, and since the rectangle qm is common to both, the remaining rectangles pR and Rn are equal,

$$\therefore \Delta H = aADd + \text{rectangle } pR + DRB - ADB$$
$$= aADd + \text{area } ApqB$$
$$= C\ \ \Delta t - v \Delta p \text{ .... (2),}$$

Where Δp is the difference of pressures represented by A and B, and v is the average volume during expansion.

The negative sign is given to $v\Delta p$, since there is a diminution of pressure in passing from state A to state B.

Equation to Adiabatic.—Suppose the expansion to be adiabatic,

$$\text{Then } \Delta H = 0 \text{ and}$$

(1) and (2) become $C_v \Delta t = -p \Delta v$ .... (3),

and $C_p \Delta t = v \Delta p$ .... (4).

Divide (4) by (3):

$$\frac{C_p}{C_v} = -\frac{v}{p}\ \frac{\Delta p}{\Delta v} \quad \dots \quad \dots \quad \dots \quad \dots \quad (5).$$

Let $\frac{C_p}{C_v} = \gamma$, that is, γ is the ratio of the specific heat at constant pressure to the specific heat at constant volume. Then (5) becomes—

$$\gamma = -\frac{v}{p}\ \frac{\Delta p}{\Delta v} \quad \dots \quad \dots \quad \dots \quad \dots \quad (5a),$$

$$\text{or } \gamma = \frac{\text{area } ApqB}{\text{area } AmnB} \quad \dots \quad \dots \quad \dots \quad \dots \quad (5b).$$

(*See* Fig. 31.)

If A and B be infinitely close, then in the notation of the differential calculus Δv and Δp become dv and dp, and (5*a*) may be written—

$$\frac{dp}{p} = -\gamma \frac{dv}{v} \quad \dots \quad \dots \quad \dots \quad \dots \quad (5c).$$

Integrating (5*c*),

$$\log. p = -\gamma \log. v + C_1,$$
$$\text{or } \log. p + \gamma \log. v = C_1,$$
$$\text{or } pv^{\gamma} = e^{C_1} = \text{constant} \quad \dots \quad \dots \quad \dots \quad (6),$$

the equation to the adiabatic line.

$$\text{For air } \gamma = \frac{\cdot 2375}{\cdot 1686} = \cdot 1408.$$

Let any two points A and B be taken close together on the same isothermal (Fig. 32). Then by

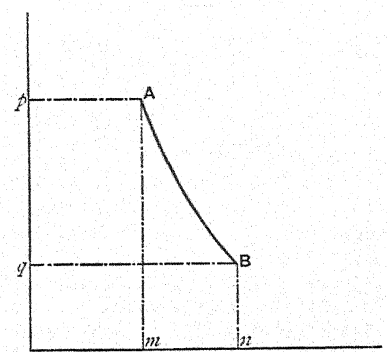


Fig. 31.

the well known property of the hyperbola the areas $ABqp$ and $ABnm$ are equal. If now pq_1 be taken equal to γ times pq, and the projector q_1B_1 be drawn parallel to OX, the area AB_1q_1p will be γ times the area AB_1nm; neglecting the small area

A B B_1. Consequently by (5 *b*) A B_1 is a portion of an adiabatic.

When A and B are taken infinitely close together, the construction becomes as follows. Draw the

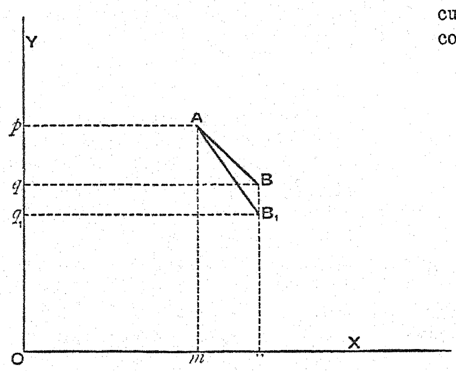


Fig. 32.

tangent A T at A to the isothermal. Draw the ordinate at A and take any point C in it (Fig. 33). Draw C D parallel to O X to meet the tangent A T in D. Take A $C_1 = \gamma$ times A C, and complete the rectangle D C C_1 D_1, A D_1 is the tangent at A to the adiabatic passing through A.

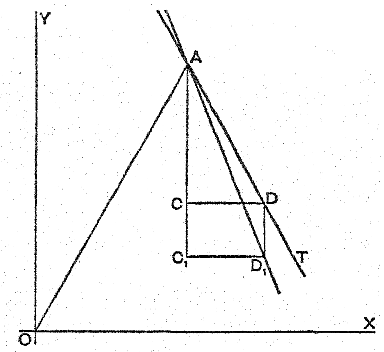


Fig. 33.

Note.—The inclination of the tangent A T to the axis O X is the same as the line joining the point of contact A to the origin O, but in the opposite direction.

Another construction. Draw two lines P P and Q Q parallel to O X (Fig. 34) 1 inch above and 1·408 inches below O X. Join O A, cutting P P in *p*, and draw *p q* parallel to O Y, cutting Q Q in *q*. The tangent to the adiabatic at A is parallel to O *q*.

Fig. 35 shows this construction applied to the drawing of a series of adiabatic curves. Sectional paper being used, the lines corresponding to *p q* in Fig. 34 need not be drawn. The lines corresponding to O *q* (Fig. 34) are not actually drawn, but the square is set to this line, and then a small portion of the curve is drawn parallel to it. The approximate curve drawn is really made up of a number of portions of tangents to the actual curve. The top and bottom horizontal thick lines correspond to P P and Q Q (Fig. 34) respectively,

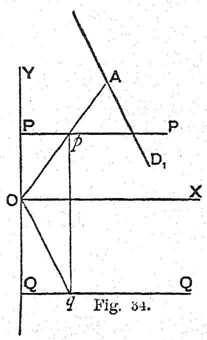


Fig. 34.

the points *p* and *q* (Fig. 34) are shown in a number of positions by the dashes on these lines. For the

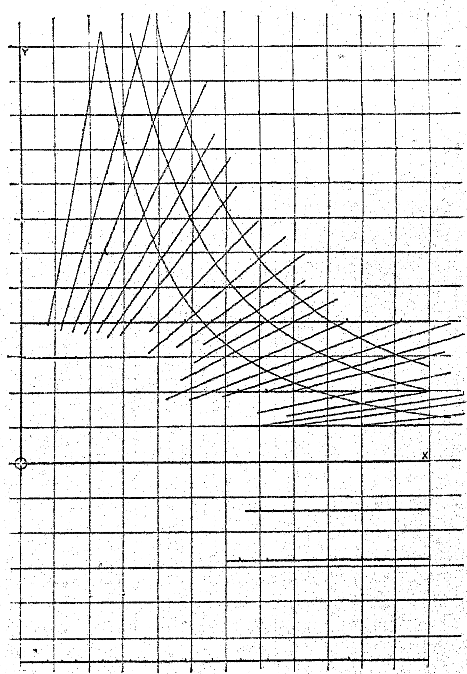


Fig. 35.

portions of the adiabatic curves near the bottom right-hand portion of the diagram the lines P P and Q Q are taken at a distance from O X equal to half the original distance.

CUTTING TOOLS.—III.

By R. H. Smith,

Professor of Mechanical Engineering, Mason's College, Birmingham.

[*Continued from p. 87.*]

CHISEL-TOOLS FOR WOOD (*continued*).

Grinding Wood Tools.—In grinding wood tools in general—not only those already mentioned, but also plane-irons, etc.—it is well to avoid the very common practice of continuing the grinding until a feather-edge is produced. This is a strip across the edge of from one-32nd to three-32nds of an inch wide, which bends over under the pressure of the grindstone when the edge is ground very thin. This feather-edge has afterwards to be removed by cutting with it across the grain of a piece of wood. Its removal means simply the loss of so much of the length of the chisel *unused*. After the feather is taken off, the thickness of the edge left is no less than can easily be obtained by carefully grinding to the limit that is reached before the bending begins to form the feather. Another advantage of avoiding the feather in grinding is that it allows one to see whether the edge has been ground to a uniform thickness throughout its width. This is impossible when a feather is formed.

Setting Edge Tools.—The most common mistake made by beginners is to use the chisel too long before re-setting the edge on the oil-stone. Suppose that half an hour's work shortens the blade, as measured to the exact cutting edge, by $\frac{1}{200}$th of an inch. To bring the edge once more to its original keenness requires a certain amount of rubbing on the stone, the amount corresponding to $\frac{1}{200}$th of an inch on the flat face. In ten minutes' work the blade will be shortened by, say, about one-third of $\frac{1}{200}$th, or $\frac{1}{600}$th of an inch, and the amount of rubbing to bring back the edge to the original sharpness after this amount of work is not more than one-third of that needed in the first case. Thus, if in the half-hour the edge be sharpened thrice instead of once, the total amount of rubbing required will be no greater than that needed at the end of the half-hour if no sharpening has been performed since the beginning of it; while in the former case the edge will at no time have become more than one-third as blunt (*i.e.*, the edge no more than one-third as thick) as it is at the end of the half-hour in the latter case. Thus, by having the oil-stone *always* at hand, clean, and in good condition, and by having very frequent recourse to it to keep the chisel edge constantly sharp, a great deal of unnecessary labour is saved, and the work is done more nicely. Of course, this rule cannot be followed unless the oil-stone is always ready to be used; otherwise, much time would be lost in getting it ready so often. This rule also cannot be adopted to so great an extent with, for instance, plane-irons, with which a considerable amount of time is lost in taking the tool to pieces and putting it together again every time the edge is set.

Paring Action.—The special characteristic of all the tools that have hitherto been mentioned is that each has a blade which follows the cut made by the edge into the wood, so as to keep the plane of the blade coincident with that of the cut. In consequence of this feature, the material removed by the tool does not need to be thrown off in short lengths, in order to leave the way clear for the advance of the tool. It sometimes gets broken in short lengths, as, for example, in cutting across the grain, but this is not necessary for the passage of the tool, and only results from the excess of brittleness of the material in certain directions. The tool passes between the wrought surface and the material removed, and simply bends this latter aside to a greater or smaller extent. The bending is, in some cases, large enough to crack it in irregularly long pieces, but it is not necessarily broken into separate bits.

The first function of the blade is to act as a support to the penetrating edge, which is pushed forward by it. Its second function is to bend aside the material sufficiently to open a passage for itself. It must be strong enough to perform these two functions simultaneously without risk of being bent or broken. It has a third function—namely, that of guiding the advance of the penetrating edge more or less nearly in one and the same plane.

The function of the sharp edge is to penetrate the material at the desired place and in the desired direction, and it does this simply by crushing a minute quantity of material in front and on either side of it, and pushing it to one side and the other, somewhat in the manner in which water is thrust to one side by a solid body entering it. Its work is facilitated by a transverse tensile strain being put on the material in front of it by the bending action of the blade, and this is more especially the case when the cut is nearly parallel to the grain of the wood.

Let Fig. 6 represent on an exaggerated scale the blade of a paring chisel taking a thick shaving (the thickness of which is exaggerated, proportionally, more than is the rest of the sketch) off a flat surface. Let the small arrows represent the splitting force which the blade exercises against the shaving, and conceive the thickness of the shaving to be divided into three layers, by the dotted lines.

As already explained, between these layers there is compressive stress at A and C, and tensive stress at B. There is also shear stress, or tendency to slide over each other, as there is between the layers of every piece of material that is bent as a beam is. These stresses tend to separate the layers from each other. Thus a thick shaving gets split up into a number of different layers of various thicknesses, according to the small differences of cohesive strength between the different fibres. As everyone who has used the chisel knows, these splits run often a considerable distance in advance of the tool. They are not always decided splits. But if the shaving be examined carefully when the tool is pressing on it (if necessary with a magnifying glass), it will be found that even when the layers are not actually pulled apart, they are on the point of separating, the delicate fibres being pulled out into a loose tangle. Thus the undermost layer is left very thin and pliable, and is easily dealt with by the sharp cutting edge.

If the material be not very coherent transversely to the fibre, this undermost layer lies closely down on the facet of the edge, and no trace of a decided split, however short, can be found immediately in front of the edge. If, on the other hand, the fibres cohere more strongly together, a small opening is found extending a short distance in front. Now this split, of course, follows the grain of the wood, which is not necessarily the desired direction of the cut. The sharpened edge has, therefore, still to perform its cutting function. It is guided by the flat face of the blade which is pressed against the already cut surface of the wood, and it cuts off and raises from the forward extension of that surface all the wood left by the small split above that same surface. It is in this case continually beginning new small shavings, just the first minute length of which is separated from the larger shaving above. The free ends of these new layers are so short that they are not perceived without very close inspection. As soon as the new layer is fairly started as a shaving, the little advance-split changes place, and runs underneath the new layer of the shaving.

Fig. 7 will give some idea of this action of the cutting edge, but it would require a still larger scale of exaggeration to show it clearly and exactly.

Power required to Pare Wood.—The power required to drive forward a tool of this description depends (*a*) on the quality of the material; (*b*) on the direction of the cut relatively to the grain; (*c*) on the thickness of the shaving; (*d*) on the angle of the tool bevel; and (*e*) on the keenness, or perfection of fineness, of the cutting edge. It forms a most instructive exercise for the student to actually measure the forces required to drive the chisel in paring different kinds of wood with

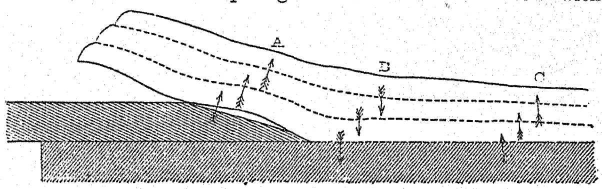


Fig. 6.

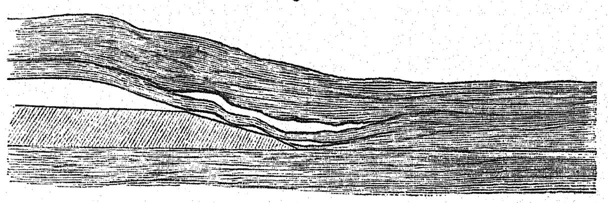


Fig. 7.

various thicknesses of shaving and various angles between cut and grain. This he should do by commencing a vertical cut fairly in the ordinary way by a thrust from the shoulder, and then loading the tool-handle with weights sufficient to continue the cut. The thickness of shaving can only be found by measuring the solid wood first before, and then after, the cut, and taking the difference between the two sizes. For yellow pine the force will be found to vary from 10 to 60 lb. per inch breadth of cut, and about double this for Bay mahogany. The force does not increase nearly so fast as the thickness of the shaving.

In cutting across the grain one part of the power exerted is spent in shoving the thin segments, into which it is easily observed that the shaving is half-broken transversely, one over the other perpendicularly to the line of the cut; and this amount of power varies nearly in proportion to the thickness, but it forms only a small portion of the whole power used. Another part of the power is spent in overcoming the friction between the chisel face and bevel and the cut surface of the wood.

CHIPPING CHISELS AND HAND PLANES.

This class of tool differs from the last chiefly in having a small angle between the under surface of the cutting edge and the cut face of the work.

Cold Chisel.—The cutting angle of the cold chisel is smaller than that of other tools for iron, it being

ground to from 40° to 70° according to the quality of metal to be chipped. The power required is lessened by making the edge keener, but at the same time durability of the edge is to a large extent sacrificed. This is readily recognised by comparing the lengths of cut that can be accomplished by a chipping chisel and a planing-machine tool before each needs re-grinding. It is doubtful therefore whether the angle of the chipping chisel would be the best if the workman's hand-power were unlimited. It is to be remembered, however, that the interruption of the work of the fitter, caused by his having to re-grind his chisel, is not of nearly so much importance as the stoppage of a planing-machine, or other power-tool, for the re-setting of the tool-edge. In the one case, only the man's time is lost; in the other, the machine as well as the man is for a certain time prevented from doing productive work; and this is equally true whether the machine is left standing while the man goes and re-dresses his tool, or whether it is stopped only long enough to change the tool, the re-dressing of the tool being handed over to another workman whose special duty it is to re-grind and make all the tools of the shop as wanted.

There is, however, a certain cutting angle for each quality of metal below which it is impossible to use a chipping chisel. The edge will be either broken or completely blunted with only one or two blows if it be ground too keen. The fitter has to grind his chisel in accordance with the quality of the metal he has to work, the proper angle being greater for the harder and tougher sorts.

Chipping Hammer.—Chipping hammers vary in weight from $1\frac{1}{4}$ to 2 lb. The best weight is $1\frac{1}{4}$ or $1\frac{1}{2}$ lb., according to the size and strength of the workman. A workman can more usefully employ his strength by hitting hard and swiftly with a light hammer than by hitting sluggishly with a heavy one. The swing should be given mostly by a motion of the wrist and not at all from the shoulder. The shaft of the hammer should be grasped somewhat loosely. The edge of the chisel should be kept moist, either by wetting it in the mouth or by dabbing it on a piece of waste soaked in oil, kept in a hole bored in the surface of the bench.

Guidance of Chipping Chisels.—The angle at which the chisel must be held to the worked surface in order that it may run neither in nor out but continue cutting a shaving of equal thickness, depends on the toughness of the material, on the keenness of the chisel-edge, and on the thickness of the shaving. A thick, stiff shaving presses the chisel-edge downwards into the material with great force—the chisel must be held closer down to the surface; the tougher the material, the smaller the cutting angle of the chisel, and the thicker the shaving. The proper angle is always found out as the work proceeds by feel, and by watching how the chips come off. After two or three blows, a good fitter sees what the right angle is, and practice gives him the power of keeping so exactly to this correct angle that he can produce a fairly smooth and accurately flat surface with the chipping chisel alone. When he comes to a place where thicker chips have to be taken off, because of unevenness of the outside "black" surface, he instinctively alters slightly the inclination of his tool, so as to prevent the stiffer shaving driving it below the level of the surface he wishes to produce.

This keeping exactly to a level surface in chipping is perhaps the most curiously delicate operation in the whole range of tool-cutting. The mathematical expression of the balance of the forces involved would be an equation of great complexity.

Penetration by Chisel Edge.—The character of the penetration of the extreme edge into the metal differs from that of the wood chisel into the wood, only because metal partakes more of the characteristics of a *fluid* than does wood. Under great pressure almost any metal, if not hardened by fire or by chemical admixture with non-metallic substances, can be made to flow or ooze from one shape to another like a viscous fluid. As the chisel-edge is thrust forward, the material makes way for its passage chiefly by this flowing movement, and the greater part of the resistance it offers to its advance is a viscous resistance. This fluidity of the material accounts for there never being any splitting in advance of the tool-edge, as there is in wood. Such splitting *rarely* occurs in chipping, even with laminous iron.

WOOD HAND PLANES.

Wood hand planes have, like the chipping chisel, a thin blade, the under surface of which is held up at a certain small angle from the surface being worked. This angle varies from 10° to 25° in planes intended for the commoner softer timbers and for the harder and more cross-grained sorts. The upper face of the blade is ground flat, there being a bevel and small facet on the under side only. This bevel is ground at an angle of from 20° to 25° to the upper face—that is, the length of the bevel is from three to a little less than two and a half times the thickness of the blade. The small facet may have an angle from 15° to 10° greater than this, so that the upper face lies at from 45° to 60° from the surface of the work.

In all the planes used by joiners, except some few for special work, such as moulding, the "plane-iron," or blade, is stiffened by having a second "top

iron" screwed down on its flat surface. This bears against the flat face only at its two ends, and, being itself thin, presses against the edge with a stiff

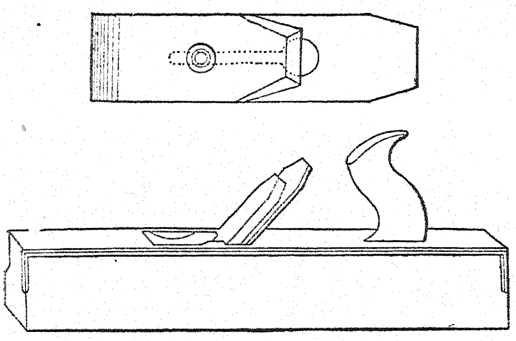


Fig. 8.

springy force. The edge of the top iron is placed close to the cutting edge—the closer the finer the shavings are desired to be—and this springy pressure prevents "chattering," that is, unsteady bending before the always-varying resistance of the material cut. The whole is held firmly by a wooden wedge in the tapered slot in the stock (Fig. 8). The top iron also serves another purpose, which will be explained farther on.

The stocks of planes are commonly made of wood. Iron stocks are becoming common in America, and to some extent are already used in England. The edge of the slit in the sole of the wooden stock wears away with the passage of the shavings past it, and after a time leaves this slit too wide. This is rectified usually by letting in a small flat plate of hard wood screwed down to the

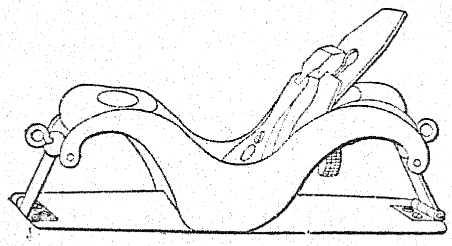


Fig. 9.

sole. A brass plate is occasionally inserted, and of course this wears much longer; but it is not advisable, because of the difficulty in getting the surface of the brass exactly flush with that of the wood. The wooden sole gradually loses the perfect flatness of its surface from the warping of the wood, from unequal wear in different parts, and from "scoring," *i.e.*, being grooved by being accidentally driven over nail-ends. The iron surface having been made once true, remains so always.

The Jack Plane (Fig. 8), for rough, heavy work, has a stock of about 14 inches in length. The iron is ground with a slightly rounded contour, so that the plane really ploughs out broad, rounded furrows. The top iron is set back from the edge about $\frac{1}{16}$ inch.

The Trying or Half-Long Plane is 20 to 22 inches long, and the Long Plane about 26 inches. These have the edge ground straight across, rounded off only a little at the corners, and the top iron should not be more than about $\frac{1}{64}$ inch back from the cutting edge.

The Smoothing, or as it is sometimes called, Hand Plane, is made of various lengths up to 8 inches long, and is used on as many different classes of work.

There are also various small planes for hollow work. An extremely useful form of iron-stock plane is shown in Fig. 9. It has a flexible sole-plate, which can be screwed up to any radius of curvature.

DRAWING FOR CARPENTERS AND JOINERS.—III.

[*Continued from p.* 91.]

JOINTS IN CARPENTRY AND JOINERY.

In building wooden structures pieces of timber are often required of length greater than can be easily procured; in such a case the member of the structure must be made up of two or more pieces "jointed" together. As the strength of any tie, column, strut, etc., is nearly always least at the joints, it follows that to get the maximum strength from the material used the joints should be very carefully designed; and having been properly designed, the drawings supplied to the working carpenters should be clearly and fully dimensioned, so that the work may be turned out as intended. Many joints used every day by carpenters do not possess 40 per cent. of the strength of the solid member, and as the strength of a structure is measured by the strength of its weakest part, it is easily seen what a fruitful source of waste of material badly designed joints are. To design the best possible joint for any given case, the forces acting on the joint, and also the physical properties of the materials of construction, must be known with a fair degree of accuracy. The influence of time and exposure to weather must also be known and allowed for. The dimensions which would give the best possible joint in, say, a tie beam of oak, would perhaps not be the

dimensions of the best possible joint in pitch pine. The "design" of structures, or of joints in structure, is beyond the scope of the present lessons, but the above remarks have been made in order to lay stress on the importance of having carefully dimensioned drawings of joints subjected to great stress. Of course, in joiner-work and cabinet

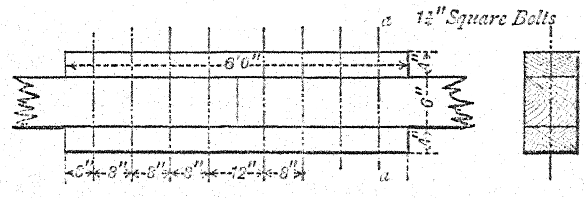


Fig. 24.

making, where the joints have no very great stress to bear, more latitude may be allowed.

Example 8.—Joint in Tie-beam (Fig. 24). Draw to a scale of 3 inches to a foot. This is called a fish joint, and is the simplest way of lengthening a beam. The fish pieces on the side of the beam are a little more than half the section of the beam. The three are screwed together by bolts. The pull on the tie-beam is transmitted by a shear on the bolts, and partially by the friction between the beam and the fish-plates, due to screwing up the bolts. The bolts should be large, so as to offer a great amount of bearing surface on the timber, or else they will crush the timber, and the joint will be weakened. For the same reason, bolts square in section are preferred to round-bodied bolts.

The bolts must be placed far enough apart and far enough from the end of the beam, or when the pull comes on the joint, a piece of timber

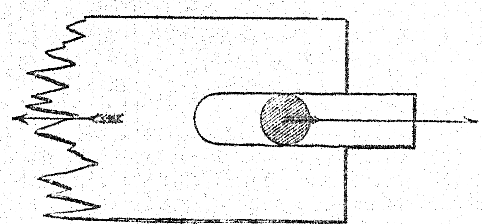


Fig. 25.

may be sheared out of the middle of the beam (Fig. 25). The bolt-heads and nuts must rest on washers similar to those in Fig. 13.

The section of the solid tie-beam is $6 \times 6 = 36$ square inches. The net section at *a a* (Fig. 24) is $(6-1\frac{1}{4}) \times 6 = 4\frac{3}{4} \times 6 = 28{\cdot}5$ square inches. This is the place where the joint is most likely to give way by direct tearing. The "efficiency" of the joint—that is, the ratio of the strength of the joint to the strength of the solid plate—is therefore $\frac{28{\cdot}5}{36} = {\cdot}79$.

The smallness of the bolts, and their consequent liability to press into the wood, is sometimes an objection to the above form of joint. Figs. 26 and 27 show two methods of jointing in which the bolts are not depended on for transmitting the pull, but merely for holding the joint together. In Fig. 26 the pull is transmitted from the beam to the cover-plates by keys. The keys must be thick enough to resist crushing into the wood. The bolts, of which three are indicated in the figure by their centre lines, merely hold the joint together, and may therefore be relatively smaller than in Fig. 24. The efficiency of this joint is the ratio of the thickness between the keys to the original thickness of

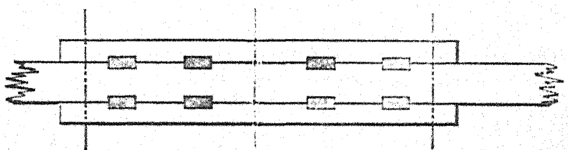


Fig. 26.

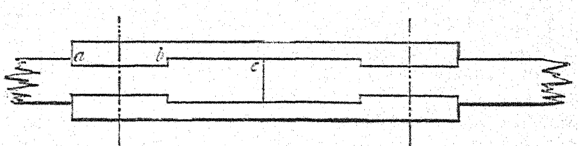


Fig. 27.

the beam. With a beam 6" square in section and keys $1\frac{3}{4}$" thick, the efficiency would be $\frac{4\frac{1}{4}}{6} = {\cdot}708$.

In Fig. 27 the joint is made by indenting the cover-plates into the beam. The shoulder at *b* must be made large enough to resist the crushing, and the distance *a b* or *b c* great enough to resist the shearing action. Two bolts whose centre lines are shown hold the joint together.

Examples 9 *and* 10.—Draw a joint for a tie-beam 6" square as shown in Fig. 26 and in Fig. 27. Scale 3" to a foot.

A scarf joint is one in which the breadth and depth of the beam are kept the same throughout the joint. In tie-beams and beams subject to transverse stress straps of wrought-iron or mild steel are often put on each side of the scarf joint, and bolts put through the timbers and straps. Fig. 28 shows a simple scarf joint, and one in which the

pull is transmitted by the bolts. Fig. 29 shows an indented scarf joint; in this bolts and straps are

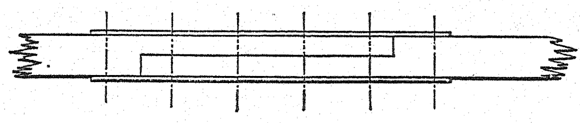


Fig. 28.

not absolutely required, but as more than half the section of the beam is cut away, in any joint subject to considerable stress they would be added to increase the efficiency. Figs. 30 and 31 show scarf joints in which the parts are brought to a proper

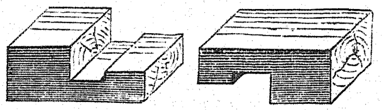


Fig. 29.

bearing by a wedge key *k* in the middle of the scarf. The end surfaces *s* are inclined, so that on tightening up the wedge key, the reaction at the surfaces *s* tends to bring the two halves of the joint firmly together. The wedge key should only be driven up tight enough to bring the parts to a bearing; if driven up too hard the joint may be

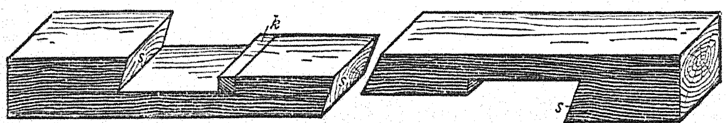


Fig. 30.

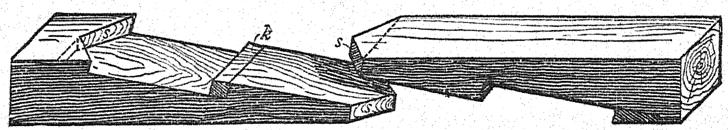


Fig. 31.

strained and injured. The scarf joints (Figs. 29, 30, and 31) may be used with iron straps and bolts.

Examples 11—14.—Draw and dimension scarf joints, such as shown in Figs. 28—31, for a beam 12″ square. Scale 3″ to a foot.

When no bolts are used the length of the scarf may be six times the depth or thickness of the beam in oak, ash, or elm, and twelve times in fir.

When the scarf depends on bolts only, these lengths should be three times and six times respectively. When bolts and indents (Fig. 29) are combined, the lengths may be twice and four times respectively the depth of the beam. These practical rules are given by Tredgold.

Figs. 32 and 33 show a compound joint *halved and dovetailed.* This joint is supposed to be supported from below as in the case of a wall-plate. Fig. 30 is a plan and elevation, and Fig. 33 is a "quasi-perspective" view of the two parts, and shows much more clearly than Fig. 32 the construction of the joint.

Fig. 34 is a joint effected by a tongue or tenon, in the one part *a* fitting into a mortise or slit of similar width in the other, *b*. Fig. 35 shows a quasi-perspective view of one part.

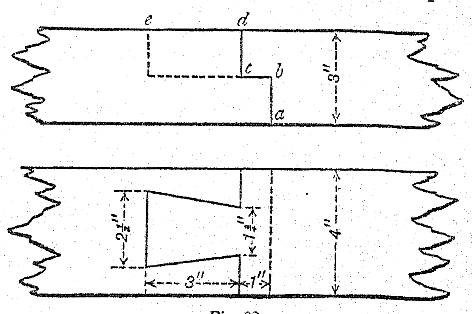


Fig. 32.

Fig. 36 shows the common method of crossing two timbers at right angles, by means of *halving*, so that they may be flush. Fig. 37 is a quasi-perspective view of the two timbers separate.

Fig. 38 shows a halved joint in which the timbers cross each other at any angle, and Fig. 39 shows the two parts separately.

Fig. 40 shows a joint where three timbers cross each other, and have all to be kept flush. The middle timber 2 is checked out at *a b c d* for one-third of its thickness to receive the timber 3. Similarly, on its other side the timber 2 is checked

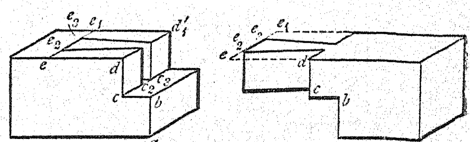


Fig. 33.

out at *e f g h* for one-third of its thickness to receive the timber 1. Timbers 1 and 3 are reduced at these places to one-third of their thickness. Lastly, where timbers 1 and 3 overlap clear of timber 2,

they are halved together—*i.e.*, at the triangles *e b k* and *d g l*. Fig. 41_1 gives a quasi-perspective view

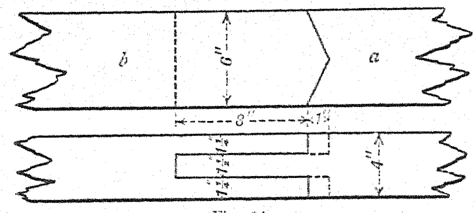


Fig. 34.

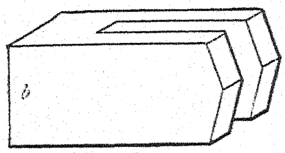


Fig. 35.

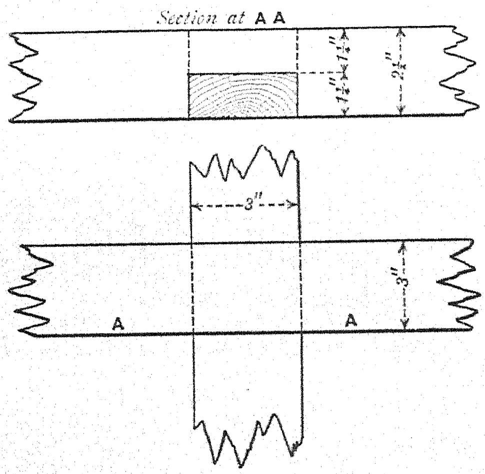


Fig. 36.

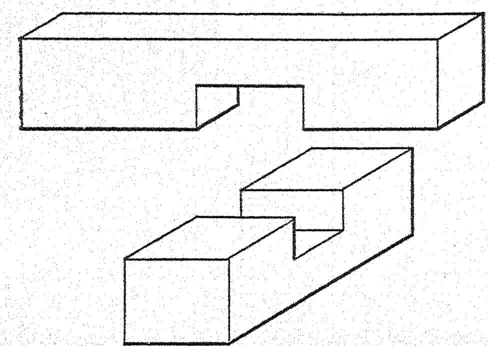


Fig. 37.

of timber 1, and Fig. 41_2 of timber 2. Timber 3 is similar to timber 1.

With this joint and with many other joints used in carpentry and joinery, it is almost impossible to

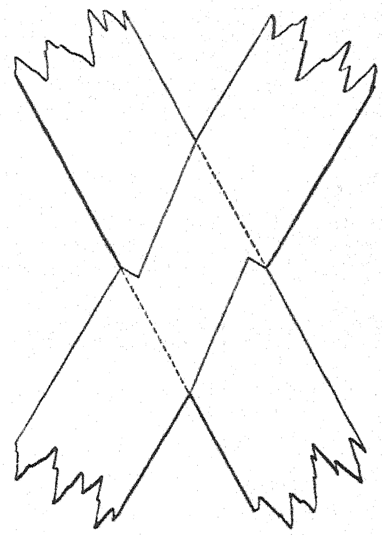


Fig. 38.

give ordinary orthographic projections that will render the construction clear and intelligible. The

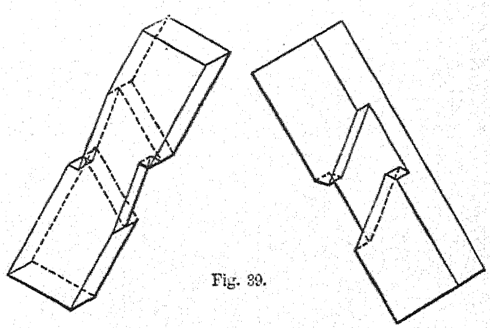


Fig. 39.

quasi-perspective views given are more intelligible. At present the student may look upon them as auxiliaries to the orthographic projections in giving him a clear idea of the construction to be represented. We will return later on to the drawing of these quasi-perspective views, and give detailed instructions concerning them. In Figs. 33, 41A, and 41B, the thin lines shown are construction lines, and will not form part of the finished drawings. Such quasi-perspective drawings may have their dimensions marked on in figures, and so form working drawings. For example, Figs. 41A and 41B, taken in conjunction with Fig. 40, will constitute a much clearer set of working drawings than orthographic projections could give. However, the two

orthographic projections given in Fig. 32 are preferable, regarded as working drawings, to the

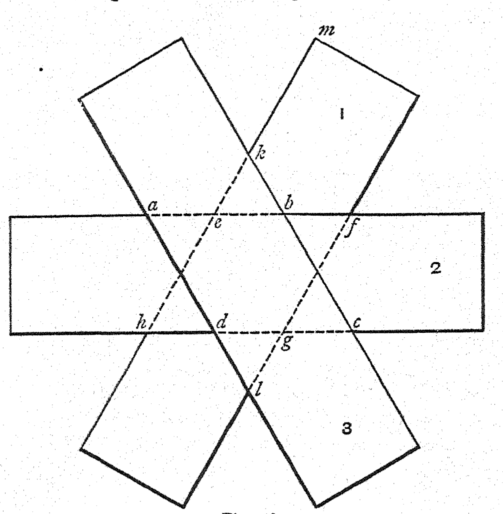


Fig. 40.

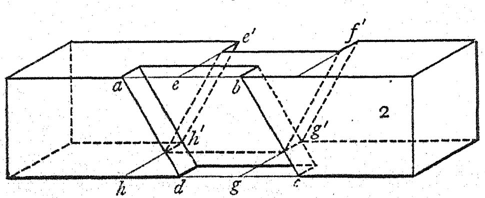


Fig. 41 A.

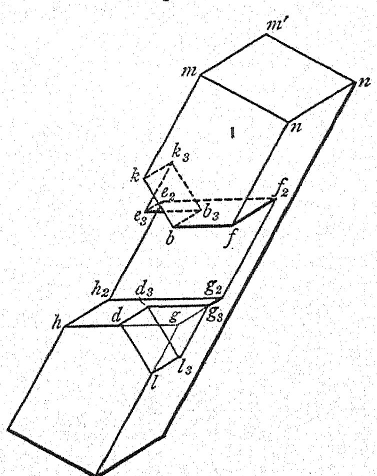


Fig. 41 B.

quasi-perspective drawing Fig. 33. As a rule, where possible, orthographic projections should be used for working drawings.

WATCH AND CLOCK MAKING.—III.

By David Glasgow,

Vice-President of the British Horological Institute.

[*Continued from p.* 96.]

THE FUSEE AND MAINSPRING (*continued*).

Fusee Stop.—The usual stop to a fusee watch is a straight piece of steel fitted to a stud in the top plate, placed so that the end of it will just catch the projecting hook of the fusee-cap when in the same plane; it is kept free of the hook by a weak spring underneath it until the chain comes on to the last turn of the fusee, when it presses the stop close to the plate, and the hook catches it.

This stop is a very good one, where there is room for it and it is well and carefully made, but in common watches it is seldom well made, and in very flat and full-plate watches there is not sufficient room for it, and its failure to act is often the cause of chains breaking. A much better stop is the solid one which is made in one piece, since instead of the blade rising at an angle, as the stop described does, it is raised and lowered parallel to the plate, thus giving more freedom to the fusee hook to pass; and, as there is no stud required, it occupies less room. It is fixed to the plate with two screws, the space between the screws forming the spring; the screw at the bend has a shoulder, and the hole in the blade fits loosely on the plain part of the screw, the head of the screw being just far enough from the plate to allow the stop to rise the required height to free the fusee hook; the spring may be made very thin, as there is no pressure on it. The end of the stop should be flat, or sloped a little outwards, so that with any undue strain the hook would press it against the plate, and it should be planted opposite the fusee arbor, the blade forming a right angle with the face of the fusee hook when in contact with it. If the blade is left too long, as it often is, the hook pushes it away, and if too short, pulls it towards the centre of the fusee, thus frequently passing it and breaking the chain.

Mainsprings.—The employment of the mainspring as a prime mover for clocks and watches, although dating from the sixteenth century, has undergone little or no change in the manner of its application. The manner in which the power is given out from the spring is second only in importance, in the construction of a timekeeper, to the controlling and regulating of the vibrations of the balance by the balance spring. The action of the mainspring requires, and has received, a good deal of consideration from watchmakers, especially those of France and Switzerland. In England also, when watches were made with verge escapements, the

adjustment of the mainspring was considered of paramount importance, as the time of the watch varied so much with that escapement with the least irregularity in the motive force; but when the lever escapement became universal, the English watch-maker troubled himself very little about adjusting the mainspring.

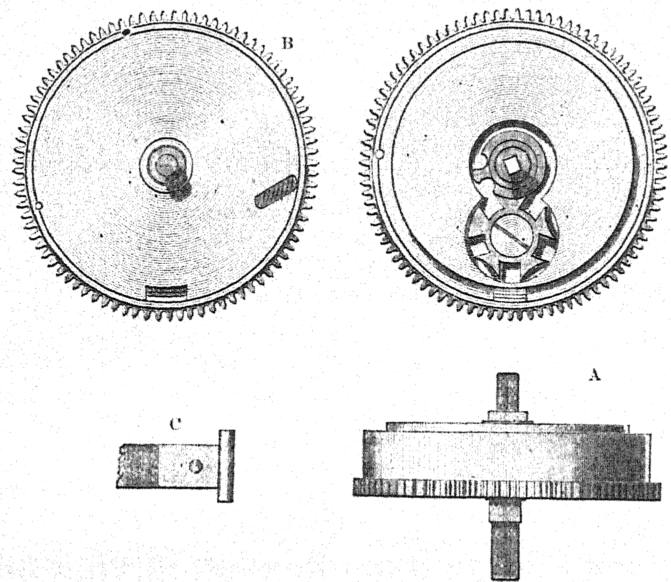


Fig. 5.—A, Ordinary Going-Barrel and Stop Work; B, Improved Going-Barrel; C, Stop Piece.

A mainspring to act with a fusee is tapered from the outer end, so that when the outer end of the spring is fixed rigidly to the barrel, the coils of the spring when being wound round the arbor will fall away from the outer circumference separately, and wind and unwind on and off the arbor without the friction produced by the coils rubbing one another, as they do with a straight spring and a loose attachment at the barrel.

Number of Turns in the Spring.—To prescribe a certain number of turns of spring for a barrel would be quite misleading, as the number of turns of the spring in the barrel is no guide to the number of turns the barrel will make by the winding or un-winding of the spring on or off the arbor.

M. Saunier quotes the following theorems from a work on mainsprings by Messrs. Rozé (father and son), which was published in Volume II. of the *Revue Chronométrique*:—

(1) A mainspring in the act of uncoiling in its barrel always gives a number of turns equal to the difference between the number of coils in the up and down position. He says:—"Thus if 17 be the number of coils when the spring is run down, and 25 the number when against the arbor, the number of turns in the uncoiling will be 8, or the difference between 17 and 25."

(2) With a given barrel spring and arbor, in order that the number of turns may be a maximum, it is necessary that the length of the spring be such that the occupied part of the barrel (exclusive of that filled by the arbor) shall be equal to the unoccupied part; in other words, the surface covered by the spring when up or down must be equal to the uncovered surface of the barrel bottom.

A good deal of stress is laid by various writers on the necessity of a proper-sized barrel arbor; but if the arbor used is too small, as it often is in fusee watches, when too thick a spring is used, the mainspring will break at the eye, unless it is made very soft at that part, when the only effect will be that it will bend round the arbor, acting as a larger arbor and reducing the acting length of the spring.

The size of arbor found to answer best, allowing of the necessary length of spring and preventing too small a circle at the eye, is one-third the inside diameter of the barrel: the arbor should be snailed, so that when the spring is wound on to it, it will take a spiral form, and not be distorted, as it would be by winding it on a circular arbor.

In order to diminish the friction of the coils in a going barrel, mainsprings have been made recently with the outer coil curved backwards, so that the spring when unconstrained takes a form something like the letter **S**. This spring is made with a view to the better separation of the coils upon the spring's unwinding, as the outer coils will fall more readily away from the inner ones towards the edge of the barrel when the spring is bent in this way than when it is straight or of the usual form. It is said to be freer in the barrel, but liable to break.

Going-Barrel and Stop Work.—Fig. 5, A, is a diagram of the ordinary going-barrel and "Geneva" stop work. Its application to all the watches made out of England, and to nearly all the keyless watches made here, renders it familiar to every

watchmaker, and any elaborate description of it is unnecessary; and, as the principle of the action of the mainspring in the barrel has already been discussed, the only feature that need be noticed is the stop work. The stop work shown in the figure is applied to nearly all going-barrel watches; but this and every form of stop work so applied has the great defect of reducing the height of the barrel, necessitating a narrower, thicker, and shorter spring, and thus increasing its liability to break. There is also the further defect of the stop drawing away the oil from the hole and pivot to which the stop finger is fitted, as, to save room, the finger must be fitted close to the barrel. The Swiss always fix this stop work on the barrel cover, but some of the Lancashire movements have it on the barrel. This arrangement is bad, for these reasons:—The barrel hole being in the same plane as its teeth, or wheel, there is more friction in that hole than in the hole in the cover, and, therefore, the pivot should be as long as possible and have oil kept to it; the sinks turned out to receive the stop work necessarily weaken the part of the barrel to which it is applied, and render it more liable to be spoilt than the unweakened part, and any injury to the cover is easier remedied than if it occurred to the barrel.

With a view principally to remedy these defects of the ordinary stop work, and also to obtain an approximate adjustment of the mainspring, I devised the barrel represented in Fig. 5, B.

Two slots are cut tangentially, as shown in the figure, in the barrel and cover, into which the pivots on the piece C project. The piece C is riveted to the end of the spring with one rivet only, this allowing of its bearing equally on either slot in case they are not exactly parallel to one another, and half the thickness of the pivots is filed away to prevent loss of spring room. When the spring is wound round the arbor, the pivots traverse the slots inwards, and, when they reach the bottom, make a strong and most effective stop.

The number of turns the spring is required to make is regulated by the length of the slots; if they are too long the spring will be wound up on itself, and, although the stop will be perfect, the friction of the coils of the spring on each other will be greatly increased (an evil that is not always considered in the going-barrel, as in many cases the whole length of the spring is used).

This barrel has the advantage of admitting a wider mainspring and longer pivots; there is nothing to draw away the oil from the holes, and there is besides a perfect adjustment of the mainspring for nearly four turns.

Mainspring Making.—The process of making a chronometer spring is so nearly identical with that of making a watch spring that a description of the former will suffice for the two.

These large springs are cut from rolled sheet steel, which must be of the best quality, with a circular cutter; the bench on which they are cut has an adjustable bar, so that the springs may be cut to any required width. The roughness left from the cutter being taken off the edges with a file, the strip of steel is then bound round with binding wire, and wound up into a spiral six or eight inches in diameter (the binding wire keeps the coils separate and the steel from scaling). It is then heated in a close furnace, and, when at a proper heat, dipped into melted tallow or oil. As steel will not all harden at the same temperature, a good deal of the art of spring-making lies in the careful hardening.

When the spring is removed from the tallow and the wire taken off, it is hard and very much distorted; it is then drawn over an iron case, heated with gas until it becomes of a deep straw colour, and in this first process of tempering it is brought nearly straight, and soft enough for further manipulation. It is now fixed in a frame, somewhat resembling the frame of a large bow saw; this frame moves along a bench on rollers, and has a screw at one end for drawing the spring tight as the heat to which it is subjected lengthens it. The spring is again placed over the hot iron case, and when the part at the end that is first submitted to the heat becomes of a light blue colour, it is drawn gradually over it until it is all of the same colour and temper: the rollers on the frame enable the operator to move it quickly if the colour is coming too rapidly. The spring is kept quite tight in the frame during the process of tempering, and when it cools all the kinks have disappeared, and it is quite flat and straight. It is next fixed up in a frame similar to the last, having one end fixed and the other adjustable, and worked smooth with lead clams and coarse emery. After all the marks have been removed, it is tapered by working the clams backwards and forwards, beginning close to one end of the spring, and increasing the length worked upon by an inch each time the clams are drawn to and fro, the operator gauging the thickness as he proceeds, and finishing with wooden clams and fine emery.

Notwithstanding the constant gauging of the spring during the process of tapering, the amount of tapering and its accuracy are tested at the last by bending the spring into double loops from end to end, and seeing that these loops grow gradually larger or smaller, according to the end first tested:

this testing requires skill and judgment. When the spring is finished with the fine emery, the eye is made at the thin end, and a small part of its length softened for bending round the barrel arbor (if it were left as hard as the rest of the spring, it would break by being bent into so small a circle): it is then wound up two or three times, and if it forms a perfect spiral, it is passed, but if any of the coils are closer together than the rest, it is rejected, as this shows it is not of uniform temper throughout.

Straight springs are so much easier made than tapered ones that they can be made much cheaper, and it can only be want of enterprise on our part that prevents us from supplying other countries with mainsprings as we have formerly done, instead of importing the greater part of what we use.

CHRONOMETER AND WATCH MAKING.

Chronometer Finishing.—The principles which govern the action of wheels and pinions are all that an intelligent workman needs to understand—apart from the practical details—in order to be able to finish well; but the proper application of these practical details can only be indicated in a book, and it requires long experience at the bench before a man becomes a good finisher.

There is a little to do to the barrel when it comes from the movement maker, namely, to smooth the pivots, and free the barrel on the arbor and let it into the frame, and hook in the mainspring.

Hooking in the Spring.—The springs have always been until recently fixed to the barrel with a square hook riveted in the spring and fitting a corresponding hole in the barrel; but lately the Swiss mode of a hook in the barrel and a hole in the spring has been adopted, because it is easier done, and if a new mainspring is required there is no new hook to be made.

Considering the necessity for perfect adjustment of the mainspring of a ship's chronometer, and the trouble taken by a good mainspring maker to taper the spring in order that the inner coils, when being wound round the barrel arbor, may fall away from the outer ones without friction, the advantages of a firm attachment of its outer end to the barrel will be at once recognised. This hook is better than the barrel hook usually found in watches, there being more room for it, and it being turned of the form of the head of a screw for wood or of a button; but whatever its form, it is not so good as the hook in the spring, and it takes up a portion of the spring room, since it must project beyond the thickness of the spring which it holds.

Planting the Wheels.—After freeing the great and maintaining-power wheels with regard to one another, and smoothing the holes in them and the arbor, upon which they will be found very tight, the spiral should be cut for receiving the chain, the number of turns to be cut on it to make the chronometer go the required number of hours being ascertained as directed at page 94. The pin holes through the arbor and the collet that keeps the maintaining-power and great wheels in their places should be broached together, and the arbor and holes smoothed from burrs. The wheels may be freed by either turning a little off the face of the collet or out of the centre of the great wheel, until they move easily with a pin fitted in. The wheels should move easily, and yet have no side play or shake; as if the collet is pinned on so that they are stiff to move, the chronometer is hard to wind, and the maintaining-power spring is prevented from acting. The centre wheel is pivoted first: it must be planted in the centre of the frame, and just be free of the pillar plate. The fusee should be planted so that the great wheel makes rather a deep depth with the centre pinion, and is free of the barrel.

Stop and Spring.—The stop which catches the fusee hook when the chain is all wound on should next be filed up and adjusted, the pin hole through the stop and stud being broached with the stop held close to the plate at the point. When a pin is fitted, the back of the stop can be filed away until it just rises sufficiently from the plate to allow the hook to pass between its point and the plate; it must then be filed to length. When the stop forms a right angle with the face of the hook, it will be the right length, the face being radial to the fusee centre: the hole in the blade of the stop must be broached a little larger than the pin, in order to allow the stop to rise from the plate.

The stop spring must not be strong, and should only touch the plate where it is screwed to it, and a notch is filed in the stop near the blade to give the spring freedom. A part of the stop where the chain presses has to be thinned so that it may not be pressed in too soon. This part may be roughly got by twisting the cord of a small bow once round the smaller end of the fusee, putting the fusee top pivot in its place, and holding the bow so that the cord is parallel to the plate, and in the direction of the edge of the barrel from which the chain would be unwound. The amount of thinning it may require can be done without putting the barrel and fusee into the frame. When the mainspring has been adjusted, the action of the stop can be tested, and any correction may be made before it is finished.

DYEING OF TEXTILE FABRICS.—III.

By J. J. Hummel, F.C.S.,

Professor and Director of the Dyeing Department of the Yorkshire College, Leeds.

[*Continued from p.* 116.]

ACTION OF VARIOUS ACIDS ON WOOL (*continued*).

Nitric Acid acts like the acids just mentioned, but it also gives a yellow colour to the wool, owing to the production of so-called xanthoproteïc acid. Because of the comparatively light yellowish colour it thus imparts, as well as its destructive action upon dyed colours, boiling dilute nitric acid is frequently used as a "stripping" agent for wool, *i.e.*, to destroy the colour in wool already dyed, for the purpose of re-dyeing (job-dyeing, rectifying mistakes, etc.). Care must always be taken not to have the acid too strong (about 3°–4° Tw.—Sp. Gr. 1·02), and not to prolong the process beyond three or four minutes.

Sulphur dioxide (*sulphurous acid gas*) removes the natural yellow tint of ordinary wool, and is the most usual bleaching agent employed for this fibre. The gas is very persistently retained by the fibre, and should always be removed from bleached wool previous to dyeing light colours. This is effected by steeping the wool in very dilute solutions of carbonate of soda, bleaching-powder, or hydrogen peroxide, and washing well. When the first re-agent is employed, the acid is merely neutralised, but with the two latter the sulphurous acid is oxidised to sulphuric acid. Should this precaution be neglected, the wool will not dye properly, or, when dyed, it may be liable to become decolorised again through the reducing action of the sulphur dioxide retained by the fibre.

30. *Action of Alkalies.*—Alkaline solutions have a very sensible influence on wool, but the effects differ considerably, according to the nature of the alkali, the concentration and temperature of the solution, and the duration of contact.

Caustic alkalies (KHO, NaHO) act injuriously on wool under all circumstances, hence they can never be used as "scouring" agents.

When they are applied hot, even though very dilute, the wool is gradually dissolved, hydrogen sulphide is given off, and the solution contains organic amido-acids and a body containing sulphur called lanuginic acid. This substance in aqueous solution has the property of precipitating all direct dyeing colouring matters, tannic acid, chromic acid, and many metallic acetates.

Solutions of alkaline carbonates and of soap have little or no injurious action on wool if they are not too concentrated and the temperature is not higher than 50° C. *Soap* and *carbonate of ammonia* have the least injurious action, while the *carbonates of potash* and *soda* impart to the wool a yellow tint, and leave it with a slightly harsher and less elastic feel.

This marked difference of action between the caustic and carbonated alkalies makes it an all-important matter that for the scouring of wool soaps should be free from excess of alkali, "soda ash" should contain no caustic soda, etc.

Calcium hydrate (*lime*) acts injuriously, like the caustic alkalies, but in a less degree.

31. *Chlorine* and *Hypochlorites* act injuriously on wool, and can therefore never be applied to it as bleaching agents. A hot or boiling solution of *chloride of lime* entirely destroys the fibre, with evolution of nitrogen gas; if, however, wool be submitted to a *very slight* action of chlorine or hypochlorous acid, it assumes a yellowish tint and acquires at the same time an increased affinity for many colouring matters. The effect is probably due to an oxidation of the fibre, since wool strongly bleached by means of hydrogen peroxide or by permanganate of potash behaves similarly. Practical use is made of it by the printer of muslin-delaine (mixed fabrics of cotton and wool), and occasionally by the woollen dyer—*e.g.*, in skin-mat dyeing, where only a low temperature is permissible.

32. *Action of Metallic Salts.*—In common with all fibres of animal origin, wool has the property of readily decomposing certain metallic salt solutions. When, for example, wool is boiled with solutions of the sulphates, chlorides, or nitrates of aluminium, tin, copper, iron, chromium, etc., a small amount probably of the insoluble basic salts of these metals is deposited within, or is attracted by the fibre, and a more acid salt remains in solution. On this fact the method of mordanting wool depends.

Neutral salts of the alkalies (*e.g.*, NaCl, Na_2SO_4) exercise no appreciable action on wool.

33. *Action of Colouring Matters.*—Wool has a marked attraction for certain so-called substantive or direct dyeing colouring matters (magenta, azo-scarlet, Congo-red, orchil, etc.) if their solutions are presented to it in a proper state of neutrality or acidity, etc.

In the case of those colouring matters which only develop colour when they combine with a metallic oxide or other mordant, the wool requires to be mordanted.

34. *Foreign Matters in Raw Wool: Yolk.*—The foreign matter, or *yolk*, enveloping the pure wool fibre possesses a special interest for the dyer because on its entire removal depends to a very large extent the success with which he may obtain fast, pure, and level colours. To the merchant and manufacturer it is also of great importance, since

the amount in different kinds of raw wool varies considerably, and influences its commercial value.

Under the ordinary commercial acceptation of the term, yolk includes all adhering impurities.

According to different observers, the constituents of "greasy" wool, *i.e.*, just as it comes from the sheep's back, may vary considerably in amount, according to its origin, as follows:—

Moisture	4—24 per cent.
Yolk	12—47 ,,
Wool fibre	15—72 ,,
Dirt	3—24 ,,

As a rule, the finer qualities of wool (*e.g.*, merino) contain more yolk than those which are coarser.

When wool is washed with water certain constituents of a soapy nature are removed—*i.e.*, alkaline oleates—also some unsaponifiable fatty matter, since the oleates cause it to form an emulsion.

To separate these two constituents, it is well first to treat the dried raw wool with ether. This dissolves principally the fatty matter, and although it also takes up some of the oleates present, repeated washing of the ethereal solution with water deprives it of the latter almost entirely.

The following substances may be distinguished in raw wool—*wool-fat* (soluble in ether), *wool-perspiration* (soluble in water), *wool-fibre*, *dirt*, *moisture*.

These may be determined as follows:—

(*a*) Weigh the raw wool, dry it at 100° C., and weigh again. The loss in weight gives the *moisture* present.

(*b*) Extract the dried wool with ether, shake up the ethereal solution with water in order to remove from it the oleates; evaporate the separated ether to dryness, and weigh the fatty residue. The weight gives the amount of *wool-fat* present.

Evaporate the separated wash-water to dryness, weigh the residue, and add the weight to that of the portion soluble in water, *i.e.*, the oleates.

(*c*) Wash the ether-extracted wool several times with cold distilled water, and evaporate the solution to dryness. The weight of the residue added to the weight of the oleates dissolved by water from the ethereal solution gives the chief amount of the *alkaline oleates* present. The wool is then washed with alcohol; this always dissolves further minute quantities of oleates, the weight of which must be added to the above. *Earthy oleates* which remain in the wool are decomposed by washing the latter with dilute hydrochloric acid; the acid is removed by washing with water, the wool is then dried, and extracted with ether and alcohol. From the weight of the residue obtained on evaporating the two last solvents to dryness the amount of *earthy oleates* present in the wool may be calculated.

(*d*) The wool remaining is dried and teazed out by hand over a large sheet of paper in order to remove dirt, sand, etc. The *wool* is washed, dried, and weighed; the *sand*, *dirt*, etc., are determined by difference.

35. *Wool-fat.*—The composition of what is here called *wool-fat* is found to be of a somewhat complicated nature. By treating it with boiling alcohol it may be separated into two portions—the one soluble, the other and larger amount insoluble in this liquid. The soluble portion consists mainly of the alcoholic and fat-like body *cholesterine*, together with *isocholesterine*, each in the free state, and probably also of compounds of both these bodies with such organic acids as acetic acid. The insoluble portion consists essentially of compounds of cholesterine and isocholesterine with oleic acid, and in lesser amount with solid fatty acids—*e.g.*, stearic acid.

Wool-fat is not a compound of glycerine, and hence is not a fat as ordinarily understood. This accounts for the difficulty experienced in removing it by mild scouring agents from so-called "pitchy wool," which contains it in excessive quantity.

36. *Wool-Perspiration.*—That portion of the yolk which is soluble in water, the so-called *wool-perspiration*, consists essentially of the *potassium compounds* of *oleic and stearic acids*, and probably also of other fixed fatty acids; it contains also the potassium salts of certain volatile fatty acids (chiefly acetic acid, ammonium salts, potassium chloride, phosphates, sulphates, etc.).

As a rule, the wash-water of raw wool has a strong alkaline reaction, due to the presence of potassium carbonate; some observers, however, have found it to be entirely absent.

In washing wool on the sheep's back, this potassium carbonate, when present, plays a not unimportant part along with the potash soaps of the yolk, in facilitating the removal of dirt, etc., from the fleece.

Dried extracted yolk contains about 60 per cent. organic matter and 40 per cent. mineral matter.

Yolk-ash consists essentially of potash salts, principally carbonates.

Maumené and Rogelet give the following analysis:—

Potassium carbonate	86·78 per cent.
Potassium chloride	6·18 ,,
Potassium sulphate	2·83 ,,
SiO_2, P_2O_5, CaO, MgO, Al_2O_3, Fe_2O_3, Mn_2O_3, CuO	4·21 ,,
	100·00

It is evident from the above that when wool is washed on the sheep's back a considerable quantity of potash is entirely lost to the farmer.

37. *The Wash-Water Products of Raw Wool.*—The great bulk of the wool dealt with in commerce is, however, in the unwashed or "greasy" condition, so that an opportunity is afforded to the woollen manufacturer of extracting the whole of the yolk, and making it serve as a supplementary source of potash.

It is interesting to know that since 1860, and based mainly upon the observations of Maumené and Rogelet, the recovery of potash salts from the wash-water of raw wool, used in the centres of the French and Belgian woollen industry, has become an accomplished fact, the annual production of potassium carbonate being estimated at about one million kilograms.

After systematically washing the wool with water, the saturated solution is evaporated to dryness. The residue is heated in gas retorts, and the gas evolved may be used for illuminating purposes. The resulting coke is either calcined with access of air or washed with water, and yields crude potassium carbonate. One hundred kilos. "greasy" wool yield 7 to 9 kilos. crude potassium carbonate, containing 85 per cent. K_2CO_3. It may not be practicable to treat the whole of the wool in this manner, but since much of the wool is washed before importation, it might be well for colonial wool-growers to examine this question of the recovery of potash salts from the wash-water of raw wool.

To the agriculturist the question is also of considerable interest, since it is evident that each year there is abstracted from the soil a large amount of valuable constituents.

Another mode of utilising yolk is that recommended by Havrez, according to whom it is the natural raw material for the manufacture of yellow prussiate of potash; the method, however, is not adopted in practice.

No attempt seems yet to have been made in England to collect separately the soluble portion of the yolk for the purpose of recovering the potash salts. The preliminary washing with water is dispensed with by the manufacturer, and the wool is at once treated with the solutions of soap, alkali carbonates, etc. This operation is termed "scouring," and will be treated of in detail in a future chapter.

Another product more recently recovered from the waste wash-water of wool is the so-called *lanolin*, which is essentially wool-fat. The method of its production will be described in the chapter on wool-scouring.

SILK.

38. *Origin and Culture of Silk.*— Silk differs entirely both from the vegetable fibres and from wool by being devoid of cellular structure. It consists of the pale yellow, buff-coloured, or white fibre which the silkworm spins round about itself when entering the pupa or chrysalis state.

The numerous varieties of silk may be conveniently divided into two classes, *cultivated* and *wild* silk. The latter is the product of the larvæ of

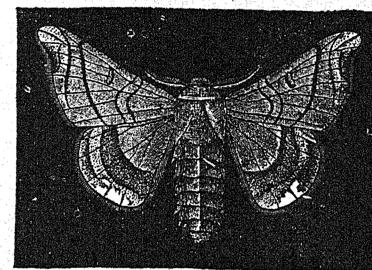


Fig. 7.—SILK MOTH (*Bombyx mori*).

several species of wild moths, which are natives of India, China, and Japan. The former and more important class is produced by the common silkworm, or caterpillar, of the moth *Bombyx mori* (Fig. 7), which has become the subject of special culture. The chief seats of the silkworm culture are Southern Europe (including the South of France, Italy, and Turkey), China, and India.

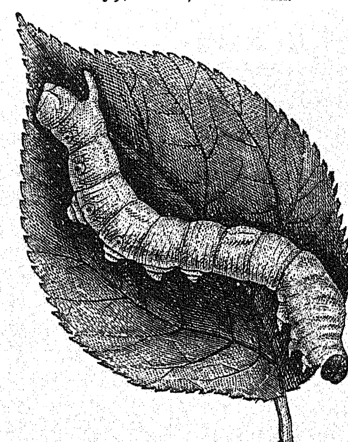


Fig. 8.—SILKWORM ON MULBERRY LEAF.

The rearing of the silkworm is mainly conducted in specially arranged establishments, called *Magnaneries*. In these the incubation-chamber is a well-lighted, airy room, where the eggs are spread out on sheets of paper resting on lattice work. A certain suitable temperature and degree of moisture are maintained for ten or twelve days. The young caterpillars, as soon as they appear, are taken to a

more roomy chamber, in which there is erected a lath framework strung across with threads and sheets of paper. Here the animals are regularly fed during thirty to thirty-three days, till, indeed, they begin to spin. Their food consists of the leaves of the mulberry tree, *Morus alba*, hence the silk is frequently termed *Mulberry silk*. During the feeding period the silkworm (Fig. 8) increases enormously in size. This necessitates a frequent renewal of the skin, and moulting takes place three or four times, at tolerably regular intervals of four to six days. About the thirtieth day the animal ceases to take food, and evinces a restless activity. At this period it is placed on birch twigs, etc., where it soon begins to spin. The silk substance, a clear, colourless, gelatinous fluid, is secreted by two glands symmetrically situated on each side of the body of the caterpillar. Each gland, as shown in Fig. 9, consists of three parts: a narrow tube (I C) with numerous convolutions, the veritable secreting portion; a central part (C B) somewhat expanded, and constituting a reservoir for the silk substance: a capillary tube (B A), connecting the reservoir with a similar capillary canal at A, common to both glands, and situated in the head of the animal.

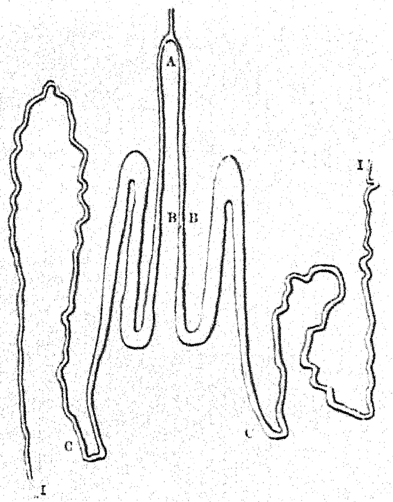


Fig. 9.—The Silk Glands of the Silkworm.

Arrived in the capillary tube at A (Fig. 9), the silk substance solidifies, and issues from the spinneret in the form of a double fibre, as represented in Fig. 10. Occasionally the two fibres may be slightly separated at intervals, and form then at these points two transparent solid cylinders.

In the beginning of its spinning operations the silkworm throws round about itself a light scaffolding, as it were, of short fibres connecting the neighbouring points of support. When this is completed, its movements become slower, and by moving its head from side to side it gradually forms and lines its dwelling with numerous layers of silken latticework.

Towards the interior the layers become firmer

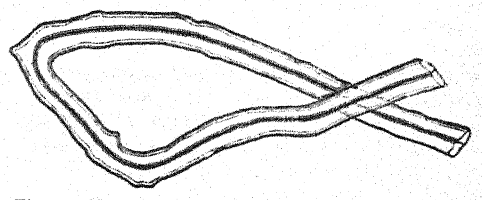


Fig. 10.—Microscopic Appearance of Raw Silk Fibre.

and denser, while the innermost one, which immediately protects the animal, forms a thin parchment-like skin. The egg-shaped product is called a *cocoon*, which may be either white or yellow.

DRAWING FOR ENGINEERS.—III.

[*Continued from p.* 113.]

PENCIL DRAWINGS (*continued*).

Example 8.—*Cast Iron Hand Wheel.*—Draw to a scale of half full size. The figures show a half transverse section, a half side elevation, and a front elevation of a portion of the wheel. These are all that is necessary to constitute a working drawing, but the student for practice may complete the front elevation. Note generally that where a number of pieces are exactly alike it is only customary to show one piece on the working drawing; the number of pieces may be indicated by centre lines.

The draughtsman must arrange his views and choose the sections so as to give information as to the form of the object represented as clearly as possible. For example, in Fig. 24 the arm is drawn in the front elevation coinciding with the vertical centre line, so that in projecting the side elevation the true length of the arm will be again seen. If in the front elevation the vertical centre line came midway between two arms, in the side elevation the arm would be "fore-shortened." Again, a section at A A would cut through the rim, nave, and arm, and, strictly speaking, in the sectional side elevation the arm should be shaded. But it is more convenient to leave the drawing as shown in Fig. 24, for then the normal section of the rim and of the nave is seen, and the arm is clearly shown in elevation.

Example 9.—*Cast Iron Wall-Box.*—Draw to a scale of half full size. When a rotating shaft is carried through a wall, the hole in the wall is

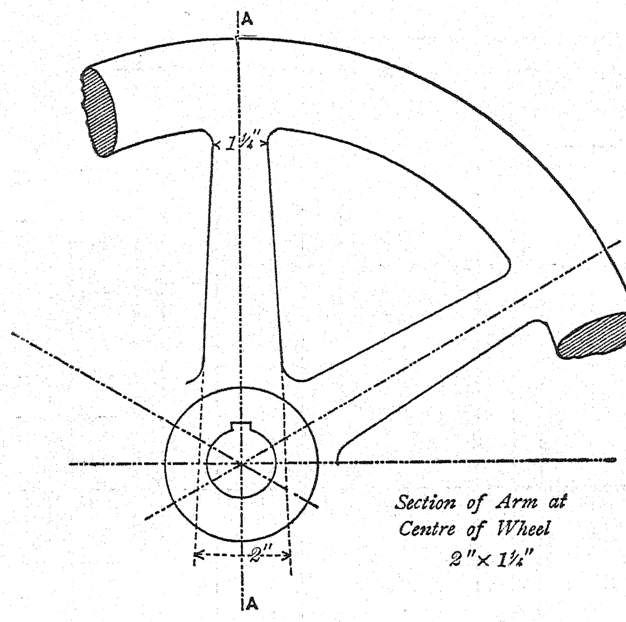
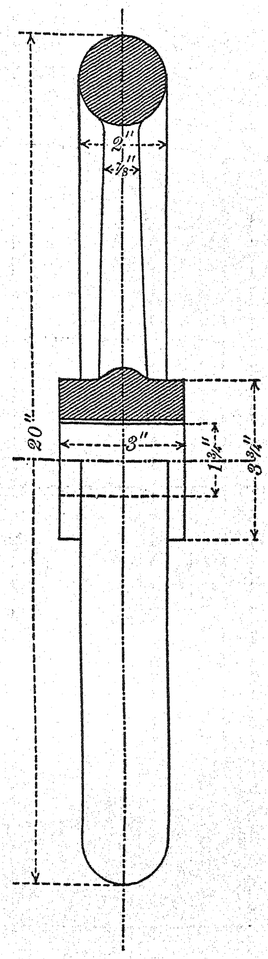


Fig. 24.



usually formed by building in a cast iron wall-box. The wall-box consists primarily of the four flat sides A, A, and carries a shelf B to which a pedestal supporting the shaft may be fixed. The sides are strengthened by the vertical ribs C, C. On the shelf B two lugs are cast for the purpose of wedging the foot of the pedestal in position. Fitting strips, $\frac{1}{8}''$ thick and $\frac{1}{2}''$ wide, project from the top of the shelf, and come in contact with corresponding fitting strips on the foot of the pedestal. The object of having these fitting strips is to reduce the surface of contact between the two pieces to a minimum, so that the work of chipping and filing to get a good fit is also reduced. Where surfaces are machined it is not necessary to provide fitting strips. The holes are elongated and give $\frac{1}{2}''$ of adjustment for the position of the pedestal. All the principal dimensions are marked on Fig. 25, any dimension not marked in figures may be taken at the student's discretion. The three projections shown are symmetrical about their centre lines, and where time is of importance, only the half projections need be drawn.

Example 10.—*Indiarubber Valve with Guard Plate and Seating.*—Draw full size.

The views shown (Fig. 26) are a sectional elevation, a half plan, and a half plan of the valve seating only.

Example 11.—Pedestal for a 3″ Shaft. Fig. 27 shows half longitudinal vertical section and a half-elevation; Fig. 28, a half horizontal section through the centre of the shaft and a half plan; Fig. 29, a half transverse section and a half end elevation. Notice that the brass bearings are thicker at the top and bottom than at the side, in order to allow for wear. If the pedestal is used to carry line shafting, the wear will be greatest at the bottom. When the bottom brass is worn down too thin, it may be interchanged with the top one. The bearing surface between the two brasses is filed down from time to time so as to keep the "slack" of the shaft in the bearings within due limits. On the outer surface of the brasses are two narrow octagonal fitting strips which bear on corresponding fitting strips of the body of the pedestal and the cap. Such a design is suitable where it is intended to fit the parts together by hand-chipping and

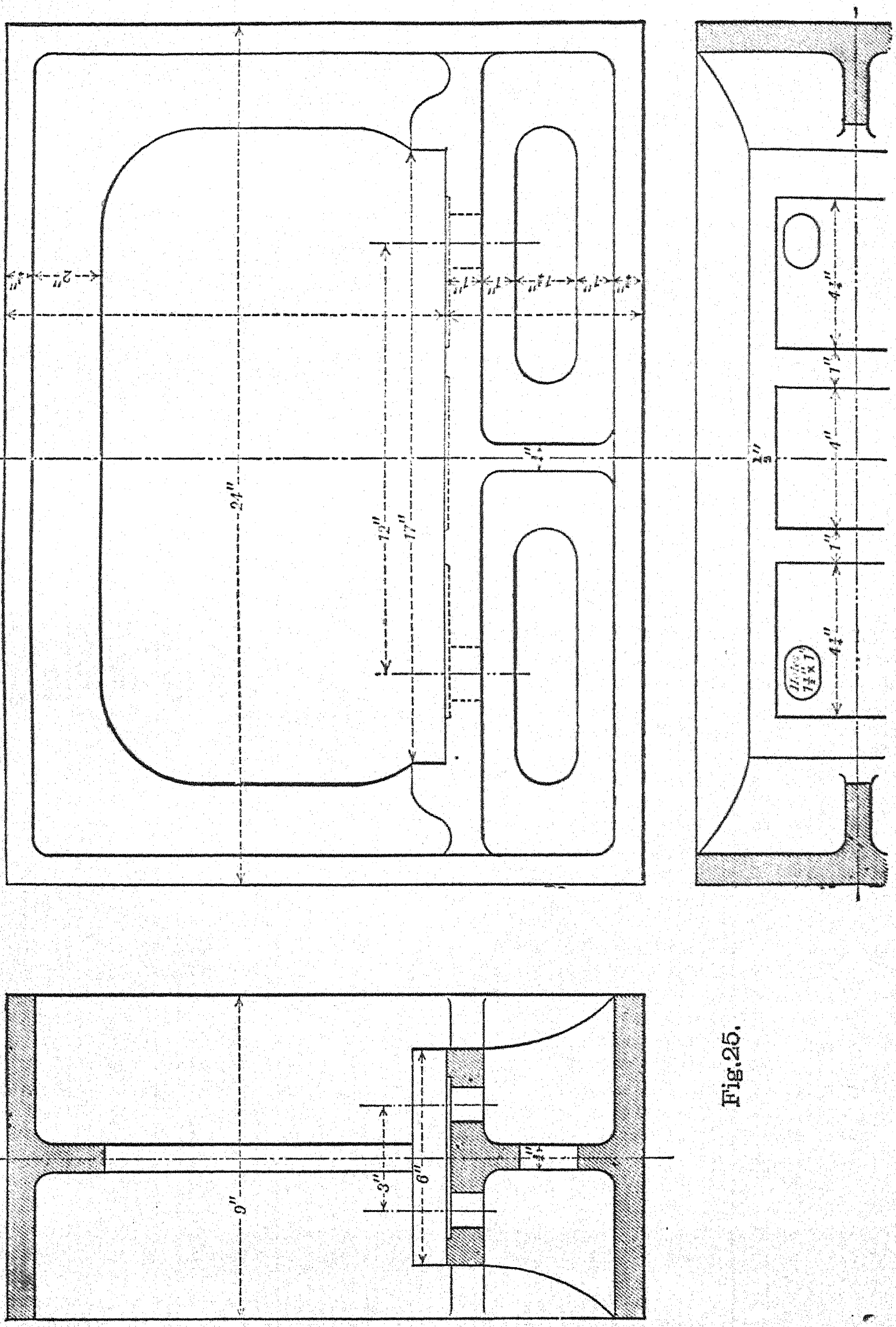
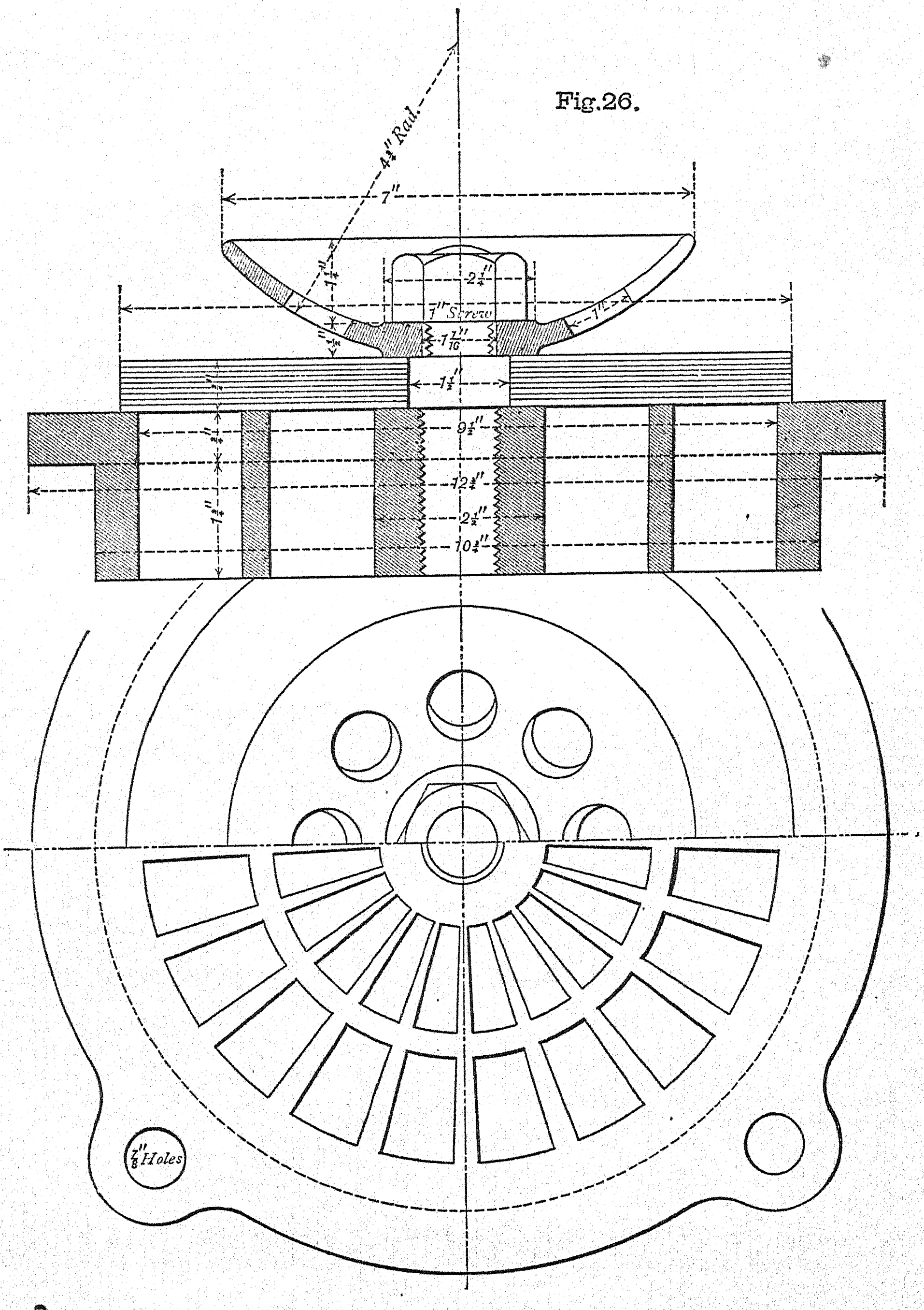


Fig. 25.

Fig. 26.



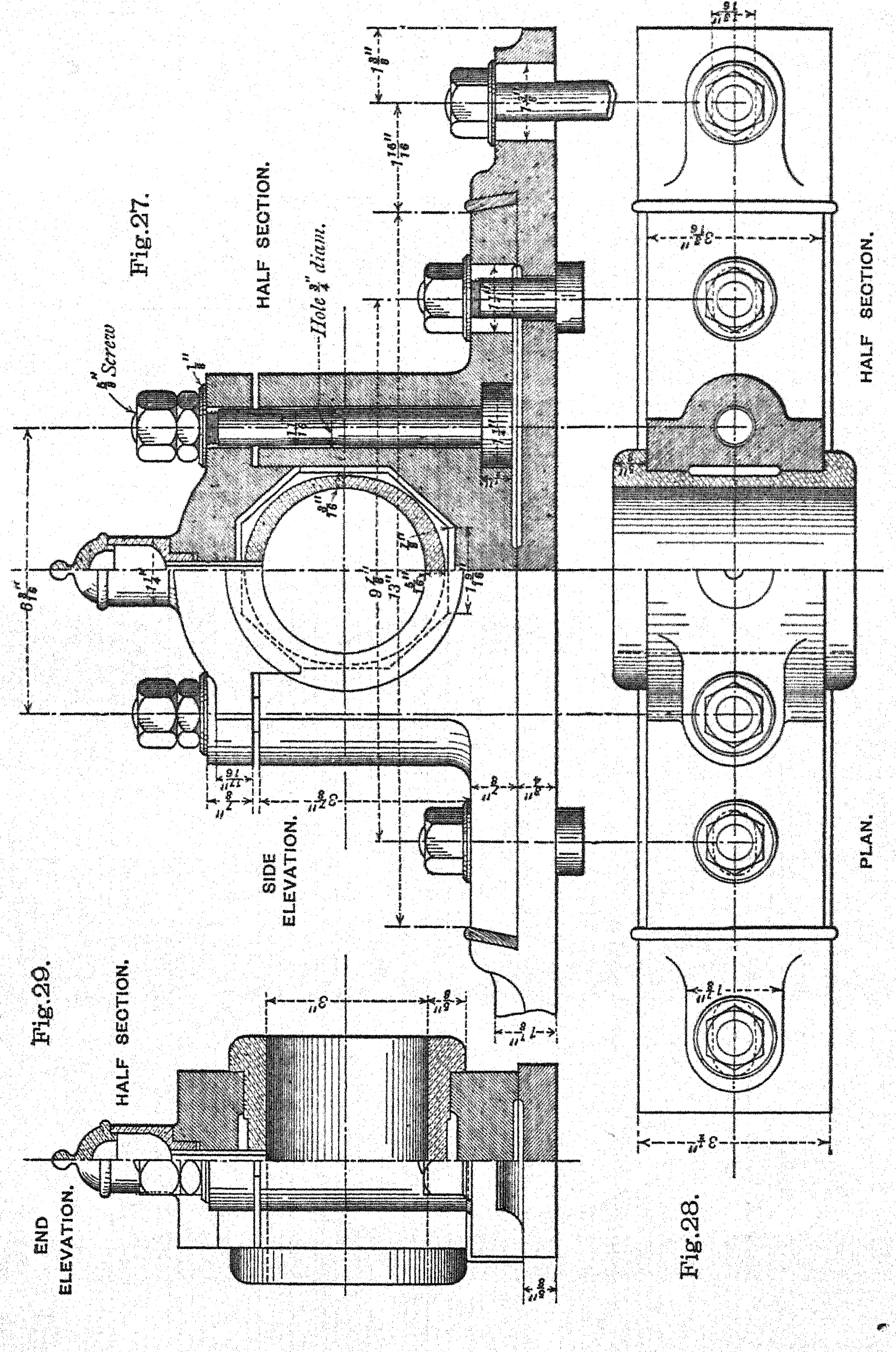


Fig.27.
HALF SECTION.
SIDE ELEVATION.
Hole 3/4" diam.
5/8" Screw
Fig.28.
HALF SECTION.
PLAN.
Fig.29.
HALF SECTION.
END ELEVATION.

filing, and to do with as little machine work as possible. When the pedestal is properly adjusted in position, wooden keys are fitted between the pedestal and the lugs on the cast-iron plate on which it rests.

The student should begin by drawing the section of the brasses (Fig. 27), then octagonal fitting strips, holding down bolt, cap of pedestal, bolts through pedestal foot and cast-iron plate in the order mentioned.

CARPENTRY AND JOINERY.—III.

By B. A. Baxter.

[*Continued from p.* 124.]

SIMPLE JOINTS AND CARCASS CARPENTRY.

Sawing.—The beginner must learn to use the saw with the same attention to his position in regard to the work as advised for mortising. Manifestly, the saw must work in a plane, and a little consideration will make it clear that the elbow as well as the wrist ought to move in the same plane, while the eye of the workman stationed above, but in or near the same plane, will be able to direct the work and glance the line, and also be in a position to detect the first departure from the line. Any error must be at once stopped, or it will increase and become incurable. It is to be remembered that if the saw wanders outside the boundary of the tenon, a chisel can rectify the error; but if the mistake is made of cutting inside the line, bad work is the result. Some practice will be necessary before proficiency is achieved. There is a form of joint similar to the mortise and tenon which is called the "bridle joint." It differs from the mortise, inasmuch as it can be sawn before chiselling out the waste wood. The opening extends through to the end, while the tenon part is cut the full width. The joint is shown in two forms (Figs. 23 *and* 24), one of which can be cut with a saw, as tenons are usually cut, while the other form will need one of the members cut with a chisel, only being outlined with the saw. The bridle joint is also available for roofing purposes. Care must of course be taken in cutting bridle joints that the saw moves entirely in the waste wood. The joining of timbers at right angles may be effected by other joints besides these—halving, dovetailing, and various combinations of both. In most of these there are two cases, as in bridle and mortise and tenon joints, one in which the timbers are joined as the letter **T**, and one as the letter **L**. In halving or dovetail-halving the same rule must be observed, and in the case of dovetails the dovetail is usually cut before the socket, which is generally marked by the aid of the cut-out dovetail, although in heavy work much labour can be avoided by cutting both parts to a template or gauge (Fig. 25); or a bevel can be used for the angle. In all cases where sockets are to be cut through, time can be saved by making several saw cuts in the waste wood before cutting out with chisel. Even in cases where the socket is not cut right through, the saw can still help a little by cutting in the waste wood.

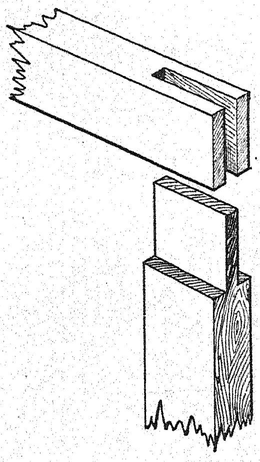


Fig. 23.

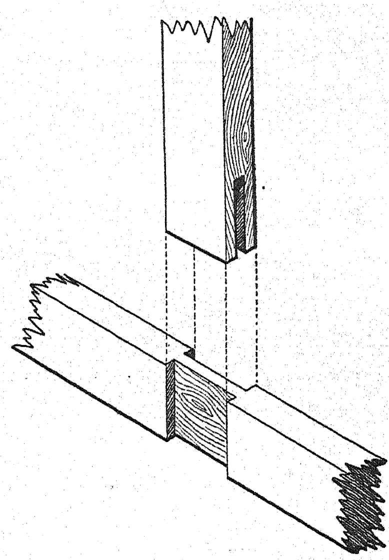


Fig. 24.

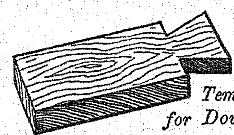


Fig. 25.

Trimming.—One of the operations which will be needed is the preparation of trimmers and trimming joists. In order to avoid risk of fire, the joists which support the flooring are not extended under the hearths in the direction of the fire-place, nor should

joists, wall-plates, or any other wood be built into the walls near any fire-place or flue. The method

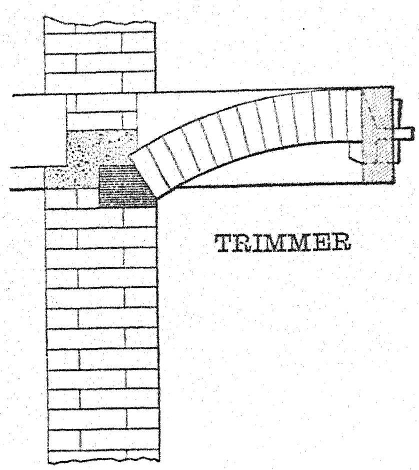


Fig. 26.

adopted to overcome this difficulty is called "trimming." It is drawn here (Figs. 26 and 27). If the joists lie parallel to the chimney breast, one about 2 feet from it is strengthened, and prepared to support the brick trimmer, which is a part of an arch abutting against the wall and the joist, and which supports the hearth-stone. The joist may be strengthened, (1) by making it stouter than the rest, (2) by the use of iron bolts and nuts, (3) or by the use of the herring-bone strut, about to be described. If the joists are at right angles to the chimney breast, then several of them are cut, and the ends formed into tenons (Fig. 28) are inserted, and supported by the trimmer, which is in turn similarly supported by two of the joists which are of full length.

Neutral Axis.—It will be admitted that if a beam or wall-plate is supported throughout its length, it matters little what mortises are cut in it, or how large or numerous, but a beam supported at the ends only, or at the ends and middle, may be seriously weakened by large or deep mortises. It will become obvious that cuts on the upper or lower surfaces of the beam are more weakening than mortises of equal depth cut in the substance of the beam, but not extending to either upper or lower surfaces. It will also be admitted that the upper part of the beam is compressed by the load, while the lower surface is put in tension. If this is so—and an experiment of two

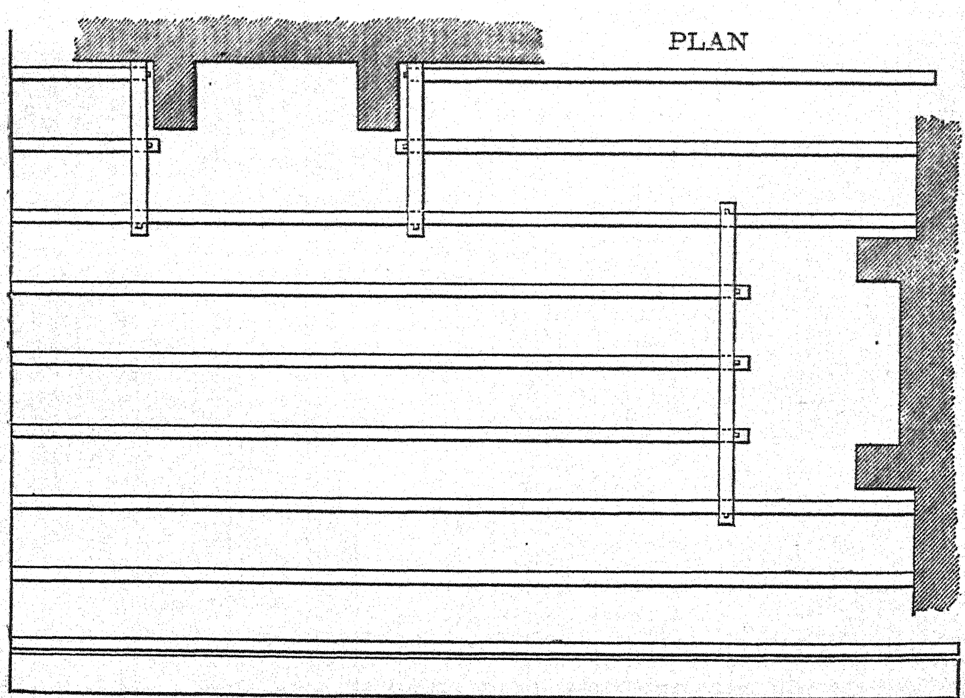


Fig. 27.

with a strip of wood partly sawn through placed on two supports will soon make it clear—if the top and bottom are exposed to a different sort of strain, then there must be some part of the beam which is practically relieved from any strain at all. This is quite well recognised, and is called the "neutral axis." It is said to be for deal about $\frac{5}{16}$ from the top surface, or about $\frac{1}{3}$, but we believe the true place is determined by the relative strength of the material to resist compression and tension, and that this neutral axis is not necessarily a straight line; this, however, is only an inference from the fact that any given weight causes more deflection as it is brought to the centre of the beam, and the fact that in cases where the beam is visibly bent the greatest flexure is in the middle of the length.

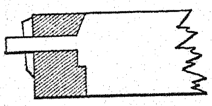


Fig. 28.

However, the neutral axis is regarded as a straight line, and mortises are therefore to be cut about $\frac{1}{3}$ from top surface in order to avoid weakening the beam seriously. Nor must the strain on the tenon be forgotten, for the joist is fixed by the tenon, and every care must be taken that it is strong enough, and yet that the mortise shall not unduly weaken the trimmer. Such a tenon is called a tusk tenon: it is generally secured by a key or wedge unless iron straps or bolts are used; the real support of the joist is not on the tenon but on the lip, and in cutting care must be taken to ensure that the lip bears the weight—the tenon is only to hold the two pieces together, which with the wedge it does very effectually, therefore the tenon need not fit tightly, and it is better to cut it just easily fitting. It is sufficient to nail a strip on the joist or trimmer

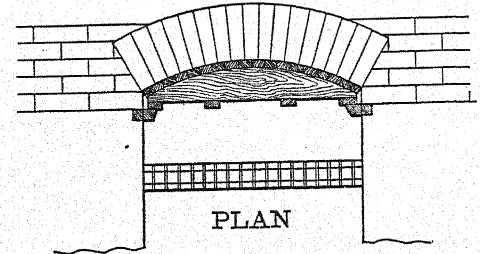


Fig. 29.

to form an abutment for the brick hearth—the bricklayer will advise upon its width and thickness.

Centres for Arches.—Probably the next article required of our carpenter will be centreing for arches of windows or doors. The points to be considered here are usefulness to the bricklayer, ease of fixing and withdrawal, and economy of labour. Much depends on the shape, for, as all readers are aware, the longer the radius the flatter the curve. A "centre" for an arch containing a segment of a large circle may be made of two pieces of $1\frac{1}{2}$ inch deal, cut to a curve having a radius 1 inch shorter than the curve required; a number of narrow pieces of 1-inch deal may then be nailed to the curved edge. Mr. W. J. Christy says: "The radius chosen is frequently equal to the distance between the upright surfaces of the opening" (Fig. 29). The whole must be strong enough to bear

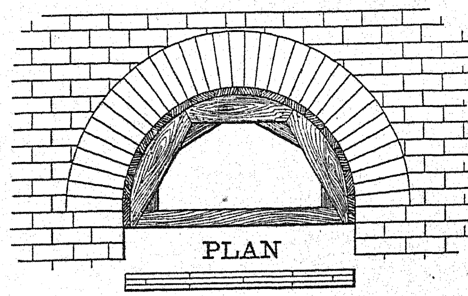


Fig. 30.

the weight of the brick arch without bending and thereby altering the curve. If the curve is a semicircle (Fig. 30) or a considerable portion of a semicircle, then the centreing must be joined together in sections, and the strips put on the edges after the pair of frames have been joined. It will be better if the pieces thus nailed on to support the bricks are uniform in width, and, though they need not be fixed close together, the spaces ought to be equal.

Sometimes these centres (so-called) rest upon pieces of quartering standing upright in the window openings, although it must be obvious that any settlement arising from the weight of the brickwork compressing the mortar joints between the courses would then be prevented from taking place, or the whole strain thrown upon the arch and its supports. Sometimes a brick is left out on each side for the reception of blocks or corbels, which support the centring while the setting of the brickwork takes place, the whole being removed and the spaces filled by the bricklayer. In every case the young carpenter, making centres or assisting to fix them, is to regard himself as working under the direction of the bricklayer, who is best qualified to direct the details of an operation which is, after all, but a means to an end, namely, a good and substantial arch conforming to the requirements of stability and the designs of the architect.

PHOTOGRAPHY.—III.

By T. C. Hepworth, F.C.S.

[*Continued from p.* 100.]

LENSES

The photographic beginner will be apt to be considerably puzzled in his choice of lenses, for each dealer advertises a large variety of these necessary aids to photographic work under all kinds of different names. But although the names are different he would be able to notice, if sectional drawings of these lenses were placed before him, that they have a family likeness and are evidently designed upon one or two standard models. Unfortunately we cannot say that because one form

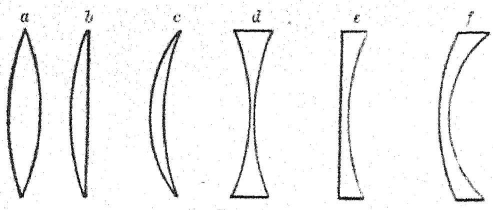


Fig. 17.

is copied from another all are equally good. For as in other articles of manufacture, there are makers of lenses who stand far above their fellows—and their instruments are known all over the world as the best that can be obtained.

We cannot here enter upon the study of photographic optics, for this subject, and the history of

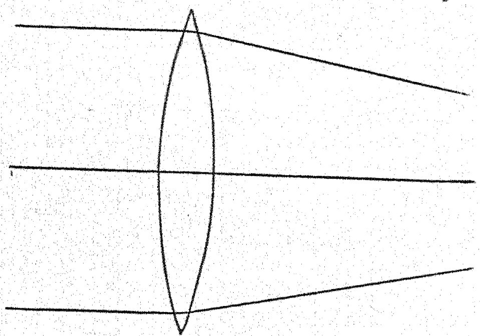


Fig. 18.

the various lenses which have from time to time been brought forward and gradually superseded by better forms, would cover fifty or sixty pages. We must therefore content ourselves with a few general remarks which will enable the reader to understand the main differences between the lenses used for different purposes.

Light travels in straight lines as long as it continues to traverse a medium of uniform density, but on entering a medium of different density it is bent out of its course, or *refracted*. The familiar instance of an oar or stick placed obliquely in water (while half of it remains in the air above) appearing bent, is due to this refraction of the light rays. A clear pool will appear far shallower than it really is for the same reason.

Photographic lenses are made of glass with curved surfaces. Glass being a denser medium than air, causes the light rays upon entering it to be refracted, and by giving the surfaces of lenses different curvatures the light rays can be bent in different directions.

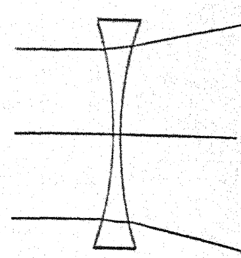


Fig. 19.

The different shapes to which lenses are ground are shown in Fig. 17, where *a* is a double convex; *b*, a plano-convex; *c*, a concavo-convex; *d*, a double concave; *e*, a plano-concave; and *f*, a concavo-convex.

Taking two of these, *a* and *d*, we are enabled to see in Figs. 18 and 19 the way in which parallel rays

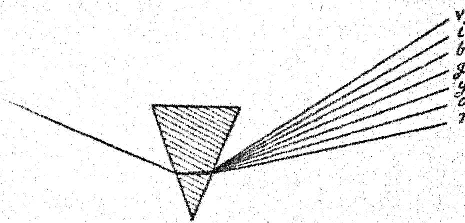


Fig. 20.

of light are bent out of their course when a lens of either kind is placed in the path of such rays. It will be noticed that the double convex lens causes the rays to be refracted and brought to a point—*i.e.*, the principal focus of the lens. Lenses which are thicker in the centre than at the edges are known as converging lenses, and bring the rays to a point as shown. But those which have their edges thicker than their centres are called diverging lenses, for they spread out the rays as shown in the diagram. These diverging lenses are not used in photography except as parts of compound lenses.

The bending back or refraction of a ray of light is best seen in the case of a prism (Fig. 20), and a lens may be regarded for the moment as a combination of such prisms. A double convex lens, for example, may be likened to two prisms with their bases in contact (Fig. 21); while a double concave

lens can be compared to a couple of prisms joined together in the opposite way (Fig. 22).

A lens is naturally full of imperfections, and it is

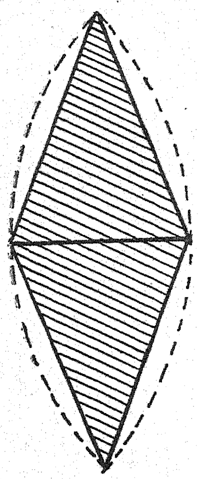


Fig. 21.

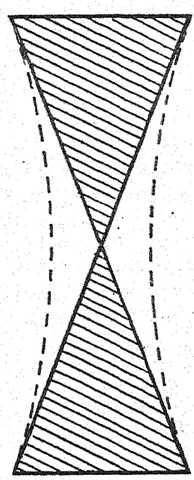


Fig. 22.

the aim of the manufacturer to reduce these to a minimum. The rays of light in passing through a lens are not all refracted to the same point, those passing through the edges of the glass being brought to a focus nearer the lens than those which pass through the centre. This fault, because it is due to the shape of the lens, is known as *spherical aberration*, and is seen in the blurring of the picture owing to the several images overlapping one another. *Chromatic aberration* also leads to blurring of the image. In Fig. 20 it is shown that white light in passing through a prism is split up into rays of various colours. Such coloured rays in passing through a prism or lens are not equally refracted, the blue and violet rays being brought to a focus nearer to the lens than the more luminous yellow, green, and red rays (*see* Fig. 23). An image

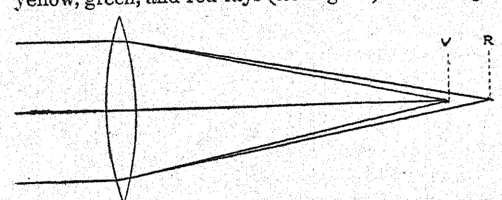


Fig. 23.

may therefore appear to be in focus to the eye, but the violet and blue rays while not so visible are more energetic than the brighter rays in causing chemical action, and therefore the plate will be blurred. This difficulty is obviated by cementing together glasses of different densities so that all the rays are brought to one point as nearly as possible. Such lenses are said to be achromatic, and these alone are now used for photographic purposes.

Curvature of field is another difficulty which has been conquered to a great extent by our opticians.

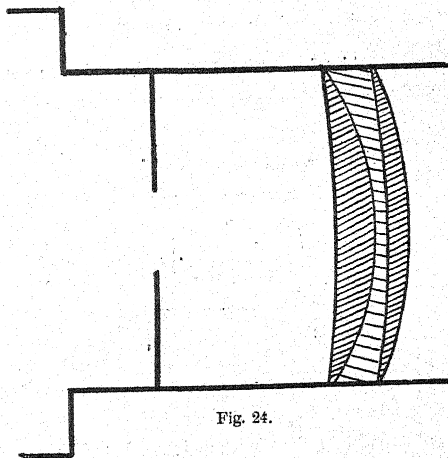


Fig. 24.

It can be seen with any lens as a blurring of the margin of the picture while the centre is in focus, and *vice versâ*. By receiving the image on a concave surface all the different portions would appear

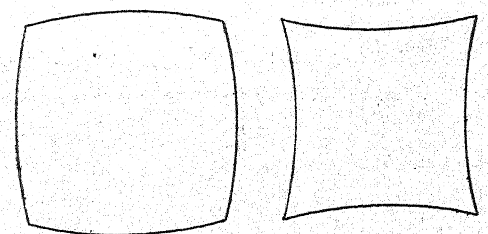


Fig. 25.

to be in focus. The fault is reduced by associating with the lens a stop or diaphragm. All lenses are furnished with such stops, while some modern ones are fitted with an iris diaphragm which can be expanded or contracted at the will of the operator.

Although, as we have seen, so many lenses are described in the catalogues of the various dealers, they may be sorted under three different heads: the *single*, or landscape lens, the *doublet* lens—otherwise called rectilinear, symmetrical, etc. etc.—and the *portrait* lens.

The single achromatic lens (Fig. 24) is the simplest, the cheapest, and for landscape work pure and simple one of the best lenses which can be employed. It cannot be used for architectural subjects, or for any purpose where straight lines have to be represented, unless such lines are far

removed from the margin of the picture. For this type of lens gives—with the stop necessary to secure good definition placed in front of it—an image which is barrel-shaped as at A, Fig. 25. If the stop is placed behind the lens, the distortion has curves in the opposite direction as at B.

The doublet lens (Fig. 26) consists of two such lenses with their concave surfaces facing one another

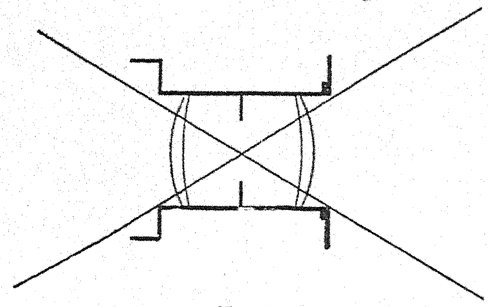


Fig. 26.

and the stop or diaphragm placed between them. We have in effect therefore a single lens with a diaphragm in front and another single lens with a diaphragm at the back of it. One form of distortion is therefore neutralised by the other, and the result of the combination is a rectilinear lens, *i.e.*, one giving straight lines.

When the photographer is limited to one lens,

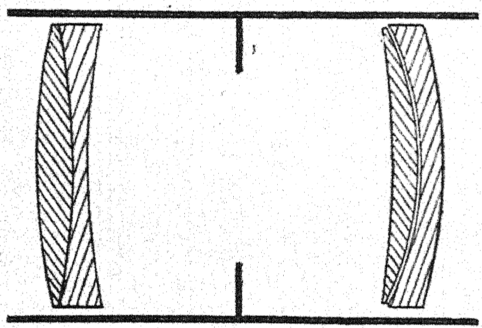


Fig. 27.

as a beginner often must be, he cannot do better than procure a good rapid rectilinear, for it is more useful than any other form of lens. It is good for architecture, for landscape, is an admirable copying lens, will take groups, and will do to a certain extent for portraiture.

A portrait lens, the construction of which is shown in Fig. 27, is far more limited in its applications. In this form of lens everything else has to some extent been sacrificed to rapidity of action. It is solely used for studio purposes, and is the chief tool handled by the professional portrait photographer. It is also an admirable lens for lantern projection purposes; and most lantern lenses, if not actually portrait lenses, are constructed on the same model with slight differences to meet the altered conditions of use.

A portrait lens must be chosen with reference to the length of the studio in which it is to be used, and preferably this length should not be less than about 25 feet. Otherwise a lens must be employed of short focus, and this can only be done at the risk of defective pictures both with regard to definition and perspective.

Two lenses of novel design have recently been introduced by our leading opticians. One of these

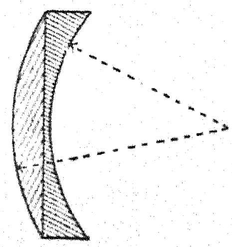


Fig. 28.

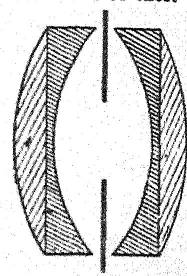
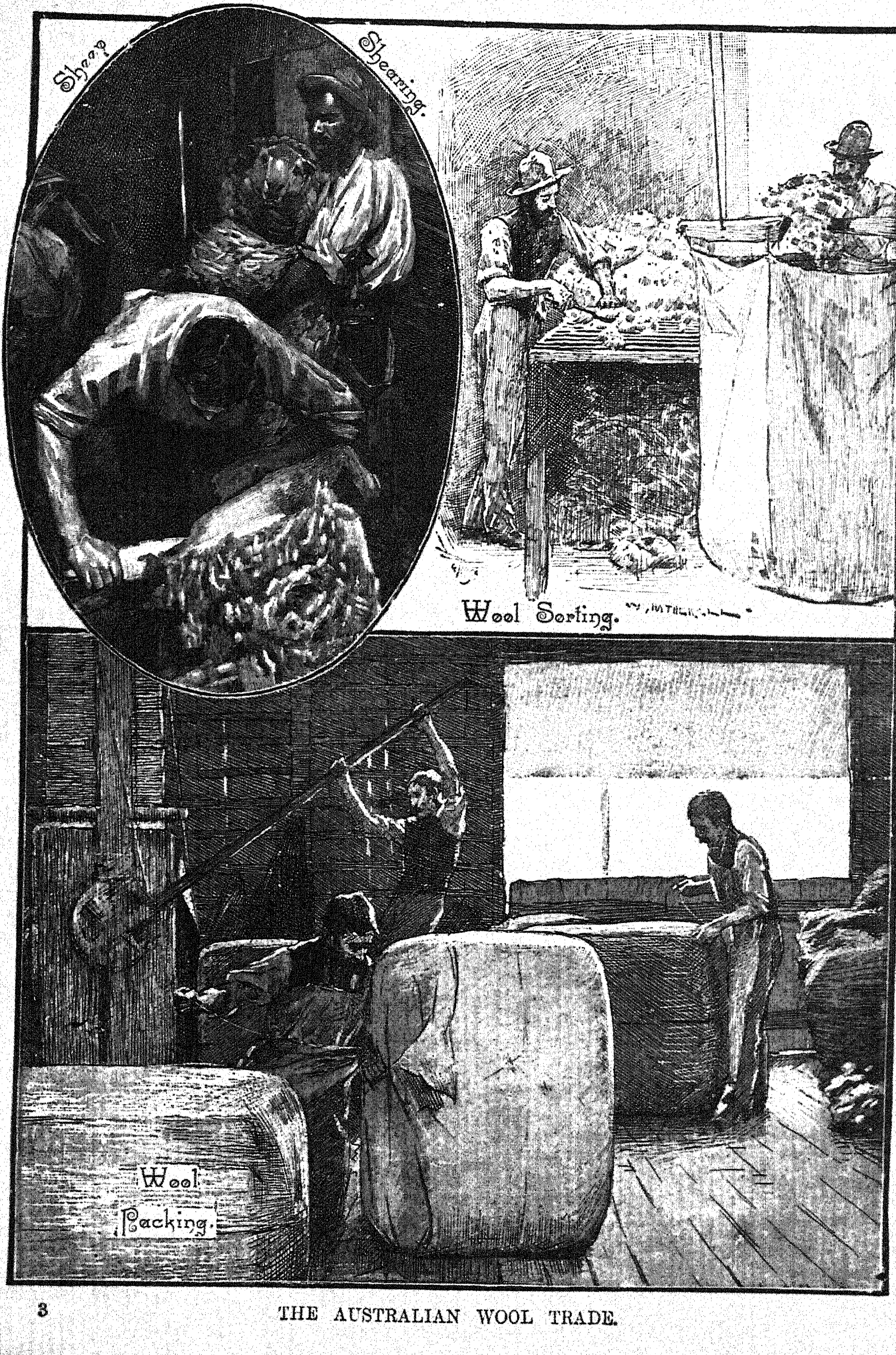


Fig 29.

is the telephoto lens of Dallmeyer, by which very large images of distant objects can be obtained; the other is the concentric lens of Messrs. Ross, who employ in its manufacture the new Jena glass. This lens is shown in section at Fig. 28, by which it will be seen that the curves of its inner or outer face are struck from one centre. Fig. 29 shows it in its complete doublet form. This lens is remarkable for its flatness of field, and is a valuable auxiliary for architectural photography as well as for copying purposes.

Diaphragms, or stops as they are commonly called, are metal plates, each having an orifice of a certain size. Any one of these plates may be inserted in the slit provided for it in the lens mount, but when the structure of the lens will allow of it, the diaphragms are cut upon a revolving plate attached to the mount itself. Recently the iris form of diaphragm has been fitted to lenses, by which any sized orifice can immediately be secured by a mechanical movement.

The principal function of the diaphragm is to cut off the marginal rays, and thus to cure spherical aberration. In portrait lenses the use of a diaphragm gives increased depth of focus. With a single lens a diaphragm is a necessity, but a rapid rectilinear can often be used with full aperture. When a small diaphragm is used, the image should


Sheep Shearing.
Wool Sorting.
Wool Packing.

be focussed under the same conditions; and this will often necessitate the use of a magnifier, or focussing glass.

WOOLLEN AND WORSTED SPINNING.—III.

By Walter S. B. McLaren, M.P.

(*Continued from p.* 129.)

WOOL-SORTING (*continued*).

20. *Wool-sorters' Disease.*—So much has been heard of "wool-sorters' disease," that its nature, causes, and method of prevention should be briefly explained. For much of the following information regarding it I am indebted to Dr. Rabagliati, of Bradford, who has devoted great attention to the disease and has written upon it. The disease first appears as an ordinary cold, accompanied with headache, oppression of the chest, and much perspiration. Then the temperature gradually becomes high, and the pulse irregular, intermittent, and weak. A cough comes on, with hurried respiration; the pulse gets weaker and weaker, till the man dies. The whole illness lasts but three or four days. If a *post-mortem* examination is held, the blood is found to be full of innumerable minute germs of fungus, known as *bacillus anthracis*.

These bacilli are quite different from blood corpuscles: they are small rods, and are accompanied by tiny particles of granular matter. The rods measure from $\frac{1}{2000}$ to $\frac{1}{1000}$ of an inch in length, and one-sixth or one-eighth of that in width. "If some fluid containing these rods," says Dr. Rabagliati, "be now placed for a few hours in a favourable position and warmed, changes may generally be seen to take place. The little rods grow by additions to their length, though the breadth remains the same, and we may observe the little rods of $\frac{1}{1000}$th of an inch spread over the whole microscopic field. As to the granular matter, which can be seen mixed up with the rods, there can be no doubt that some of it is spores, or seeds capable of reproducing the whole organism. The spore often divides into two by a transverse division, and these again each into two; so that a spore originally single may become four. If these subdivisions be watched in favourable circumstances, they may be observed to lengthen out at one side till they produce the little rods, and these in turn lengthen out, as we have already seen, till they obtain a comparatively great length."

21. *Theory of the Disease.*—Now the theory is that these bacilli pass with the dust from certain classes of wool into the lungs of the sorter, and thence into his blood. Dr. Rabagliati sums up the proof as follows: "The organism can be found in the washings of infected wools. It can be found in the blood and tissues of men who have been in contact with such wools. When the fresh blood containing it is injected under the skin of animals, the animals will die in from one to four days, and their blood and tissues will in turn be found loaded with the organism. Blood from these last animals may be employed in a similar way on other animals, and with like results. Ordinary blood, fresh or putrid, has either no effect when injected into animals, or if it has, will not produce this organism." The name "wool-sorters' disease" is, perhaps, too vague, and the malady should rather be called "anthracæmia," implying a disease in which the *bacillus anthracis* is found in the blood.

22. *Nature of the Disease.*—Until lately it was believed that the disease was caused by the putrefaction of simple animal matter, such as pieces of skin and blood adhering to the wool, which poisoned the blood of the sorter; but the researches of Dr. Rabagliati and others show this to be incorrect. How, then, does the *bacillus anthracis* get into the wool? The Angora goat, the Peruvian alpaca sheep or llama, and sheep in all countries, are liable to a disease known as splenic fever, which is caused also by this same *bacillus anthracis*, and is practically the same as wool-sorters' disease. Those animals which have it die, and their owners, unwilling to lose the wool, shear it off and pack it with the wool from the rest of the flock. It is either infected by the mere fact of the animal having the disease, or some part of the skin is clipped with it and thus carries the germs. These fleeces are called "fallen fleeces," and can be distinguished from the rest; one of them, if infected, may contaminate the whole bale, and thus cause the sorter to run the greatest risk. Though all sheep may have this disease, yet it is found that the danger arises chiefly from the following wools, all of which are imported full of dirt and dust, both animal and mineral:—Van mohair, which is the worst of all; Persian wool; camels' hair; alpaca; Turkey mohair; brown mohair; Cape mohair; and cashmere from Tibet. The total quantity of these is comparatively not great, and means could be taken to reduce the danger arising from them.

23. *Best Preventive.*—The obvious preventive, as Dr. Rabagliati points out, is to exclude fallen fleeces when the wool is being packed, and to have all the wool washed, either before shearing, where that can be done, or before packing where the former is impracticable. If this were done, there could be no danger of the recurrence of this fatal disease, and, apart from the saving of life, it would

be the cheapest method that could be adopted. At present these bales contain immense quantities of dust, specimens of which Professor Frankland has analysed. He finds that the dust of Van mohair contains 58 per cent. of animal matter, the rest being mineral; the dust of brown mohair has 51 per cent. of animal matter, and that of alpaca 40 per cent., much of which must necessarily contain impure and poisonous matter, to say nothing of the fatal fungus germs which go with it.

24. *Method usually Employed.*—The method for removing the dust employed by those firms who use these dusty wools is generally somewhat as follows:—The bales are cut open in a small room with a false floor consisting of an iron grating, a couple of feet above the real floor. A trunk or shaft is conveyed from this space to the open air, and in it is fixed a circular fan which revolves 700 or 800 times a minute. It draws the air from the room where the bales are being opened, and blows it out into the air; in doing which, so strong a draught is created that all the dust, which comes out in clouds from the bales, is drawn down and rarely rises to the height of the opener's head. In this way the opener is able to shake much of the dust from the fleeces, and to give them to the sorter comparatively clean. In some mills, notably in that of Messrs. Clough, of Keighley, this principle is carried still farther. The wool-sorters' boards run down the length of a long room. In the sorting-board, opposite which each man stands, is a grating about 15 inches square covering the top of an air-tight trunk. These trunks are all connected with each other below the boards by means of a longer one which runs the entire length of the room. Attached to this is a fan of great power which draws all its air from the gratings, and blows it out of doors, carrying with it almost every particle of dust which comes out of the material which the men are sorting. Owing, no doubt, entirely to this simple but effectual safeguard, no case of disease has been known in this mill. Other remedies have been suggested, such as subjecting the wool to great heat to kill the germs before sorting, or washing it in hot soap and water, and sorting it while still damp, but these are open to many objections, and might not in the end prove effectual. The only thorough remedy must be applied before the wool is packed—that is, to keep out diseased fleeces, and to wash the wool whenever possible.

WOOL WASHING AND OILING.

25. *Yolk on Wool.*—Having thus far examined the nature of wool and seen it sorted into its different qualities, we come to the important, but too little cared for, process of washing. Before the fleece is clipped from the sheep's back it is dirty, not merely with earthy matters, but with grease or "yolk," or *suint*—a yellow oily substance, which is a saponified grease, soluble in cold water, and which is mainly caused by the accumulated sweat of the preceding year, and by a secretion from the glands of the skin. As might be expected, this yolk is found most abundantly on sheep in hot climates, and prevails to such an extent that the clean wool is often only one-third of the total weight of the fleece, the remainder being yolk and dirt adhering to it. Merino fleeces average 40 per cent. of yolk, 27 per cent. of earthy matter fastened by it, and 33 per cent. of wool, though these figures naturally vary according to the district in which the sheep have lived, and take no account of the excessive moisture which the wool may contain. The yolk itself, or sudorate of potassium, consists mainly of potash, animal oil, a small quantity of carbonate of potash, traces of acetate of potash and of muriate of potash. There is also a certain amount of lime and fat mixed with it, which tends to make it less easily soluble. This yolk is of much value in softening and preserving the wool while it is growing, for it both oils it and keeps the sheep warm, thus tending to produce sounder and better wool. The greater quantity of the yolk, or *suint*, is generally found on the shoulders, where the wool is finest, and where also the flesh is superior in quality. In hilly countries farmers smear their sheep over with salve, which is supposed to keep them warm during the cold autumn nights before the new fleece has had time to grow long or the fresh yolk to be formed.

26. *Sheep-Washing.*—It is obvious that all the yolk must be removed before the wool can be used by the manufacturer, and this should be done in such a way as not to injure the fibre of the wool. In most cases the farmers wash or half-wash the fleece before shearing, and though this has some advantages to the manufacturer the gain on the whole is very doubtful. The yolk, in consequence of the potash and oil in it, is a most valuable manure, while the animal dirt which may be adhering to the fleece is also worth preserving. The farmer, however, loses it all by washing the sheep in a running stream. The old-fashioned way of doing this was for two men to stand in a pool in the stream, take one sheep at a time, plunge it in the water and scrub it till it was moderately clean, and then let it run about for a few days till it was dry, when it was shorn. A later improvement is to put each sheep in a perforated box or barrel, and then wash it, the effect being the same. A still more thorough and wholesale way is in use in Australia, where the sheep are fastened into pens

underneath iron perforated pipes. Water is forced into these pipes with great pressure, and allowed to run some time till the sheep are half washed. They then go singly down a passage till they come to the stream, into which they are plunged, and from which the only egress is by swimming down a small tunnel, thus ensuring a still further soaking. At the other end of this tunnel the sheep is held by a man under a very strong shoot of water forced through a pipe, by means of which the cleansing process is completed. In a few days the sheep is again dry, and can be shorn. All these methods, however, have the defect of losing the yolk; but when it is remembered that in order to wash, say 1,000 sheep and preserve the dirty water so that either it might be spread upon the fields, or the potash and grease be extracted from it, a number of tanks and other appliances would be needed, it seems rather doubtful whether the saving would pay. Nevertheless the waste of the present system is undeniable.

27. *Advantages and Disadvantages of Washing Sheep.*—It may be asked, Why should the farmer wash his sheep at all? why not send the fleeces unwashed always, as many do from Australia and elsewhere? The advantages of sheep-washing are: (1) That if it is well done the colour of the wool is improved, whereas if not done at all, the wool, if it lie long after shearing, may become a little stained with the grease, and so always have a yellow tinge. (2) If the washed wool is one-third of the original weight of the fleece, then two-thirds being washed away, there should be a proportionate saving in the cost of carriage, which, from Australia, is a large item. (3) When the manufacturer sees the wool washed, he can value it more exactly, knowing from experience what it will yield; but with unwashed wool it is exceedingly difficult to estimate correctly what the result will be. To set against these advantages there are two serious drawbacks. (1) Wool washed before shearing is not always so soft as that with the yolk left on it, because when the oil is all washed out, the horny nature of the wool causes it to get hard, and to lose its silky feeling. (2) The manufacturer loses the benefit of the potash, etc., in the yolk, which he can extract from the dirty soap-suds, and thus one of his sources of income—though a small one—is diminished. The advantages and disadvantages to the manufacturer are perhaps pretty evenly balanced, but the total loss to the farmer of good fertilising manure is undoubted, and much to be regretted.

Dr. Bowman, who devotes considerable space to a discussion of the chemical composition both of wool and of yolk, states that from every 1,000 lb. of raw wool there is on an average 140 to 180 lb. of dry sudorate of potassium, which is equal to 70 to 90 lb. of pure carbonate, and 5 to 6 lb. of sulphate and chloride of potassium. He also states that, "when wool is thoroughly washed in water so as to remove all the soluble *suint*, and is then treated with alcohol, the latter solvent extracts a solid and a more soluble liquid fat or oil. The quantity of these two substances amounts to from 16 to 20 per cent. of the total weight of the washed and dried wool, and varies with different kinds of wool. These two fats may be separated from each other by their different degrees of solubility in alcohol, and were examined by Chevreul, and named by him respectively, Stearerin (wool-suet) and Elairerin (wool-oil)." The former is a solid fat, melting at 140° F., and the latter at 60° F. These fats may also be extracted from the wool, though not so readily, by the use of alkaline liquids; and in proportion as they are extracted the wool is injured. It is therefore necessary to use a method of washing which, while it cleanses the wool from yolk and dirt, does not injure its chemical composition, or draw from it the fat which gives it both softness and strength.

28. *Adulterated Soap.*—The chief requisite for the manufacturer in wool-making is to have a soap which will clean the wool perfectly without injuring the fibre, and which at the same time is cheap and unadulterated. There is nothing which is more easy to adulterate than soap, and nothing in which detection is more difficult. The injury done to woollen goods by impure soap is great, especially when they have to be dyed a delicate colour. For instance, a yellow singed appearance is given by using soap with much resin, or much alkali; the fibre of the wool can also be burnt if the soap is too strong, especially if the water be very hot. But apart from injury to the wool, the loss in money is great if a soap is made up with silicate of soda, and of potash, resin, potato-starch, and water. Common salt, too, is often mixed with soda-ash used in soap, and even earthy matter is put into it to give weight. A recipe for testing soap is to dissolve one ounce of soap in a given quantity of water; put it into a long test glass, and add a quarter of an ounce of diluted sulphuric acid, or less. The acid neutralises the alkali; the grease and resin, if any, float on the top, and the earthy matter falls to the bottom. It is a mistake to suppose that soft soap necessarily contains more water than hard soap. The reverse may easily be the case. Soda soaps are hard, potash soaps are soft, because it is the nature of these materials to make soaps, of which they are leading constituents, hard and soft respectively. But as a soda soap will

take up four times as much water as a potash soap, and still remain firm, the temptation to adulterate in this way is great. Some soda is often put into professedly potash soaps just because it will hold so much water.

29. *Effect of Hard Water.*—If washing or dyeing is to be well done, the water must be soft. The two chief causes of hardness in water are carbonate of lime and sulphate of lime. The former can be precipitated by boiling the water, but as this is too costly where water is used in great quantities, it is never done. The effect of hard water is well stated by the *Textile Manufacturer:*—"When hard water is used for dyeing or cleaning purposes, without being previously softened, the lime it contains, in many cases, destroys and precipitates the dye-stuff, and in all cases immediately attacks and decomposes the soap used. The alkali in the soap, that is to say, the soda or potash with which the soap is made, leaves the oil and tallow with which it has been combined (forming the soap), and unites itself with the carbonic and sulphuric acids contained in the carbonates and sulphates of lime. The lime thus thrown out of combination with the sulphuric and carbonic acids immediately unites with the oil and tallow, forming what is called an insoluble lime soap—a pasty greasy substance, which has no washing properties whatever. This is deposited on the fibre of the wool or textile fabric undergoing the scouring operation, and renders the dirt or grease upon them far more difficult to remove. This insoluble lime soap has often a most disastrous effect on goods which subsequently have to be dyed, causing spots and uneven dyeing, owing to the insoluble lime soap sticking to the fibre of the fabric, and in many cases being only partially removed by subsequent scouring."

It is estimated that each degree of hardness in the water kills from 1 to 1·7 lb. of good soap per 1,000 gallons of water used. This is entirely wasted, and it is clear therefore that the soap can have no effect on the wool till the lime in the water has finished its work, and is entirely united with the alkali of the soap. Then the washing begins, but now the soap has to wash out not only the original dirt from the wool, but also the insoluble lime soap which has settled on it; thus making for itself, as it were, work to do.

30. *Means for Softening Water.*—The lime therefore should previously be removed by some other means. Soda crystals, soda-ash, and caustic soda are often used, but as the former are carbonates of soda, that is, are already in combination with carbonic acid, they cannot do the work so quickly or so well as soda in a free state. They also require the water to be heated. It is necessary also to use exactly the right quantity according to the degree of hardness of the water; for if more is used than is required to act on the lime in the water, the surplus remains free and injures the wool. Dr. Bowman states that he treated a sample of wool with an alkaline solution of caustic soda which contained 5 per cent. of soda, and he found that the same fibres of wool which on an average carried 500 grains before treatment, only carried 440 grains afterwards, showing a diminution of 12 per cent. in strength, and proving that serious deterioration had taken place. It is not safe therefore to trust to the softening of water in the washing bowl by the ordinary men employed as washers. The process is much too important, as the future spinning properties of the wool depend upon it. It is better to employ a separate tank with the apparatus known as the Carrod Water Softener, by which the softening process can be carried on effectually and more cheaply.

As most waters contain carbonate of lime, it is a waste to use soda to precipitate it, because the same result can be obtained by using lime only, and at a cost so much cheaper as to be almost nominal. For instance, 1 lb. of lime should soften the same quantity of water as 4¾ lb. of soda. If lime be taken at 12s. 6d. per ton, and carbonate of soda at £6 5s., it proves that £3 10s. worth of lime will have the same effect as £100 worth of soda. The saving is still more striking when compared with the cost of using soap to soften the water, for one cwt. of lime, costing 7½d., if properly used, will soften as much water as a ton of soap. To obtain such a result, however, a regular water-softening apparatus must be used. The accompanying figure shows the Carrod Water Softener (Fig. 3), which is available either for the lime or lime-and-soda process. The lime process consists in mixing a certain ascertained proportion of strong lime water with the water which requires to be treated. The lime thus added combines with the carbonic acid which holds the carbonate of lime in solution in the water, and the result is an insoluble precipitate of lime. The machine is automatic in its action, the opening or closing of one tap starts or stops it. The lime, or whatever reagent is used, is mixed with water in iron tanks placed above the clarification tank, the former tanks being in duplicate, so that the mixture can be prepared in the one while the other is in use; and thus the continuity of the process is secured. The water to be softened is admitted into the clarification tank through a mixing-trough, a proper proportion of the reagent passing in at the same time and well mixing with it. The requisite quantity is known by an analysis of the water and

regulated by the size of the nozzles. The respective supplies of the water and the reagent are kept regular by causing the feed in each case to

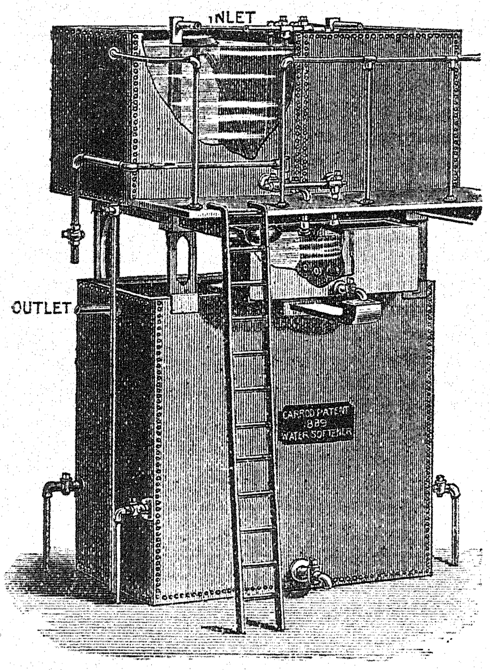


Fig. 3.

pass through regulating tanks, which are fitted with ball valves, and thus the same head of water is ensured at all times. The water, after passing through the mixing trough, enters the clarification tank by means of a pipe carried to the bottom; it then passes upwards, and by the time it reaches the outlet it has become perfectly soft, clear, and fit for immediate use. The lime and other solid matters have fallen to the bottom and can be drawn off from time to time.

Many hard waters contain not merely carbonate of lime or magnesia, but also sulphate of lime. This is not affected by the lime water. To remove the sulphate, the process requires the addition of soda to the lime in calculated quantities before mixing with the water to be softened. In some cases soda alone can be used.

The following are two examples of the effect of softening water by this process. The first is a case of most unusual hardness, and therefore the cost is much above the average.

Analysis of water before and after being treated with 3·18 lb. of carbonate of soda and 0·957 lb. of caustic soda per 1,000 gallons:—

Before.	Grains per gallon.
Sulphate of Lime	29·47
Sulphate of Magnesia	33·18
Chloride of Sodium	4·62
After.	Grains per gallon.
Sulphate of Lime	1·46
Sulphate of Magnesia	18·93
Chloride of Sodium	4·95

Analysis of water before and after being treated with lime only:—

Before.	Grains per gallon.
Sulphuric acid	22·22
Lime...	11·74
Magnesia	5·00
After.	Grains per gallon.
Sulphuric acid	21·70
Lime...	2·24
Magnesia	3·40

The cost of this per 1,000 gallons was one farthing. It is obvious of course that this process is invaluable for water used for boilers, as well as for wool-washing and dyeing, for incrustation is practically prevented.

PRACTICAL MECHANICS.—III.

By R. Gordon Blaine, M.E.,

Assoc. M. Inst. C.E., &c.; Senior Demonstrator and Lecturer on Mechanical Engineering and Applied Mechanics at the City and Guilds of London Technical College, Finsbury.

[*Continued from p.* 120.]

CENTRES OF MASS AND AREA—THE LEVER—VELOCITY RATIO AND FORCE RATIO OF MACHINES—MECHANICAL ADVANTAGE, REAL AND HYPOTHETICAL—PRACTICAL CALCULATIONS.

CENTRE OF GRAVITY OR "MASS-CENTRE."

If a homogeneous body contains a point such that it bisects all straight lines in the body drawn through it, that point is called the *centre of mass* or centre of gravity of the body. The former term is the more accurate, but the latter the more common term.

An application of the law of moments enables us to find the centre of gravity of many bodies, especially such as are of uniform thickness, like a disc or plate. The same method which enables us to find this point in a uniform plate enables us to find the similar point (centre of area) in an area of the same shape or outline. The method of finding the centre of gravity of a solid, such as a pyramid or cone, is scarcely within the province of these lessons, being usually dealt with in books on theoretical mechanics. As an illustration of the law given above, however, one or two cases of interest will now be worked out. Suppose, for example, a circular disc (Fig. 17) of uniform thickness 6 inches in radius has a square hole of 4 inches wide cut out

of it, the centre of one side of the hole being on the centre of the circle, find the C.G. of the remainder.

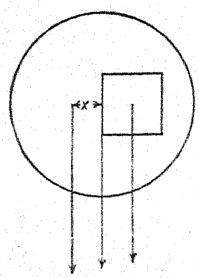


Fig. 17.

We have here three forces to deal with: the weight of the complete disc acting through its centre, the weight of the square acting through its centre, and the weight of the part of the disc remaining after the hole is cut out, this force acting through the point whose position we seek.

The algebraic sum of the moments of the last two forces about any selected point must balance the moment of the first, since we may imagine the disc to be composed of the two parts yet complete, for it is evident that the moment of the whole must be equal to the sum of the moments of its parts about any selected point whatever. Selecting the centre of the disc as our point of reference, and remembering that the moment of a force about any point on its own line of action is zero—since the perpendicular *distance* is 0—we have

$16 \times 2 =$ moment of weight of square about centre of circle.

(For our purpose *area* may be taken as weight, for the disc being of uniform thickness the weight of any part is simply its area multiplied by a constant number.)

$(3{\cdot}1416 \times 36 - 16) \times x =$ moment of cut disc about same point.*

Since these moments act in opposite directions, they must be equal or their algebraic sum must be 0, hence

$$16 \times 2 = 97{\cdot}097 \times x$$

$$\text{or } x = \frac{32}{97{\cdot}097} = {\cdot}33 \text{ inches.}$$

The point required is therefore on the diameter passing through the centre of the square and at a distance of ·33 inch to the left of the centre of the circle. Many useful questions may be worked out in a similar way.

In all questions where the forces considered are due to the weights of loads or parts the forces are, or may be considered as, parallel. They are really directed to the centre of the earth, but owing to the great distance of the latter in comparison with any distance we are likely to have to deal with, the forces may be taken as parallel. The centre of gravity is really that point in a body through which the resultant of all the forces, due to gravity acting on the different portions of the body, always passes if we turn the body into different positions. If we go into the matter very accurately, it becomes evident that only a certain class of bodies *have* a centre of gravity, though all homogeneous bodies have a centre of mass.

Sometimes we may require the amounts of *two* resultants of a number of parallel forces. Thus a very common and useful question is to determine the supporting forces of a horizontal beam loaded with vertical loads. Suppose, for instance, we are given a beam A B (whose weight may be neglected) supported and loaded as shown in Fig. 18, and are required to find the amounts of the two supporting forces x and y.

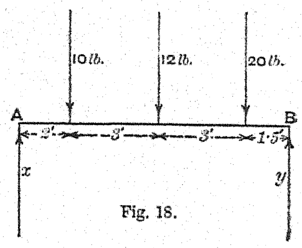


Fig. 18.

Taking moments about the point A, the moment of x will then be 0, and the sum of the moments of the separate loads must be equal to the moment of the supporting force y:—

$$\text{Hence, } 10 \times 2 + 12 \times 5 + 20 \times 8 = y \times 9{\cdot}5,$$

$$i.e., 20 + 60 + 160 = 9{\cdot}5\, y,$$

$$\text{or } y = \frac{240}{9{\cdot}5} = 25{\cdot}26 \text{ lb.}$$

Since the two supporting forces must be together equal to the sum of the loads,

$$x = 42 - y = 16{\cdot}74 \text{ lb.}$$

This question can also be solved graphically by the method for forces not acting through one point, described in the last lesson, and as the method is extremely useful in many cases this example will now be worked out.

In Figs. 19 and 20 the graphic solution of the question is shown. Fig. 19 represents the beam with its loads as before. Fig. 20 shows the corresponding force polygon, which really consists of consecutive straight lines, A B representing 10 lb., B C 12 lb., and C D 20 lb. to any convenient scale. It is evident that the supporting forces, being together equal to the sum of these loads, will form one line equal in length to A B + B C + C D, *i.e.*, to A D. This line should be coincident with A D, but I have drawn it a little to one side to avoid confusion. The only matter to be settled now is the proper division of the line, representing the supporting forces, into two parts. To do this, choose any pole O, and join the pole by straight lines to the points A B C D, which may be called "corners"

* The student is probably aware that the area of a circle is obtained by multiplying the square of its diameter by ·7854, or the square of its radius by 3·1416.

of the force polygon. Taking *any* point on one of the supporting forces—say, m on the force x—proceed to draw the link polygon as in a previous example, taking care to have through the space A in Fig. 19 a line parallel to O A in Fig. 20, and so on. The link polygon as thus found is *not* closed; but we know that if the forces are in equilibrium it must be closed, hence we close it by drawing the line $m\,n$. Now in Fig. 20 draw the line O E parallel to the line last drawn in Fig. 19, and this line O E gives us the point of separation in D A required. It is found on applying the scale that one supporting force D E or y is 25·2 lb. and the other E A or x is 16·8 lb., which agrees with the answer as found by calculation. In this particular case the graphic method does not offer a better or quicker solution, but the student should take every opportunity of making himself familiar with the method, because in many cases it is decidedly superior, for practical purposes, to the older method of solution.

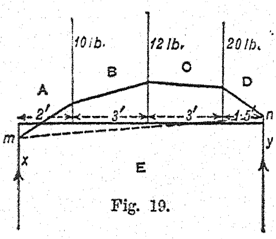


Fig. 19.

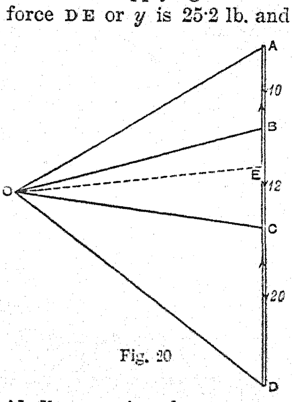


Fig. 20

This "graphic" method may also be applied to finding the centre of mass of a uniform plate or the centre of area of an area, since it enables us to find the line of action of the resultant of a number of parallel forces acting on one plane. The question looked at graphically is not likely to present much difficulty. The forces may be taken simply as the areas of the different portions of the area divided up by parallel lines, each area being obtained approximately by multiplying its mean length by its breadth. Notice that the force polygon in each of these cases becomes a straight line, the successive loads acting downwards parallel to one another, the resultant or resultants acting parallel to these but upwards, and in amount just equal to the sum of the loads. In the case of the centre of area it will be necessary to find the position of the resultant for *two* directions of the forces, *i.e.*, after the resultant is found in one position, let the area be turned round through an angle—say 90°—and the operation repeated. The two lines showing the position and direction of the resultant in the two cases will cross at the centre of area required. The practical man will do this, probably, by cutting out a uniform plate of the given shape, suspending it from a point near the edge, and suspending a plumb-line with bob attached from the same point, marking the direction of this line, and then repeating the operation for another point of suspension, the body being turned through an angle which should be nearly 90°. Balancing the plate on a knife-edge also offers a ready practical solution. The examples referred to here have been given rather as illustrations of useful methods than on account of their own importance.

THE LEVER AND ITS COMBINATIONS.

Of course the student will see that any question regarding the equilibrium of a lever can usually be settled by an application of the law of moments. Let moments be taken round the fulcrum or point about which the lever turns, and the algebraic sum of the moments of all the forces acting on the lever must be zero if there is equilibrium. If the fulcrum is not at the centre of gravity of the lever, then the weight of the lever itself will form one force, which must be taken into account. Combinations of levers present little difficulty. Thus in Fig. 21 the lever A B has arms in the ratio of 4 to 1, hence a force of 40 lb. will be required at B to balance the load of 10 lb. at A. But the force may be applied by the longer arm of another lever C D; and as in the figure the arms of this lever are in

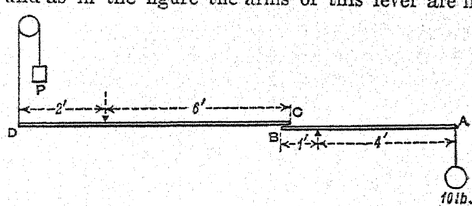


Fig. 21.

the ratio of 3 to 1, it is evident that the force P must be equal to 3 times 40 or 120 lb. if there is to be equilibrium. Combinations of this kind are very often used, as for instance in weighing machines, and it may be interesting to close this part of the lesson by the solution of a practical question of this kind.

Fig. 22 is a sketch of a weighing machine, M N being the platform on which a load W is placed. The weights of the various levers, etc., and their dimensions being given as in the sketch, it is required to find the load on the platform which will be balanced by the movable weight of 30 lb. when

that weight is 3 feet from the fulcrum E of the weighing lever E F. Let us begin with the lever E F, the condition of equilibrium for it is as follows:—

$30 \times 3 + 5 \times 1 = x \times \frac{1}{2}$, where x is the pull in the rod G D at *its lower end*. From the equation

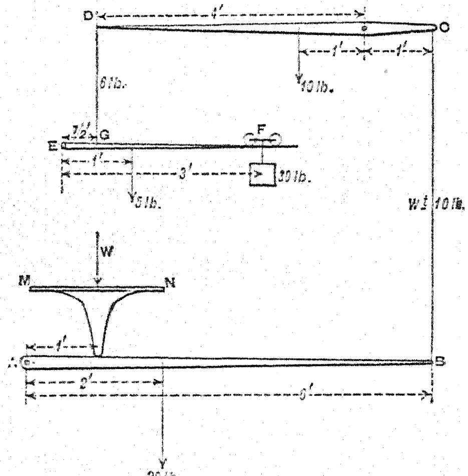


Fig. 22.

x is evidently 190 lb., the pull in the rod G D at its *upper end* is 190 + the weight of the rod = 196 lb. This will readily be understood on considering that if the rod were loaded merely by its own weight the pull on it at its lower end would be 0, and at its upper end 6 lb. Add the load 190 lb. to both, and the result is as stated.

Now considering the lever C D, its equilibrium gives us the condition $196 \times 4 + 10 \times 1 = y \times 1$, where y is the pull in the rod B C at its *upper* end.

From this $y = 794$ lb., hence the pull in B C at its lower end is $794 - 10 = 784$ lb.

The last lever A B will be balanced if

$$784 \times 6 = W \times 1 + 20 \times 2,$$
$$\text{or } W = 4664 \text{ lb.}$$

Thus the load on the platform is 4,664 lb. when the movable weight occupies the given position.

The reader who has followed carefully what has been done in the solution of this question will not have any difficulty in solving any ordinary question connected with levers. Remember to take moments about the fulcrum—as affording the shortest solution, and take *all* the forces into account.

In the older books different *orders* of lever are spoken of, but these "orders" are not now recognised. The same law applies to all levers, and there is no object in complicating matters by considering as a new "order" of lever one in which the fulcrum is changed into a different position relative to a certain load or loads.

The student should make himself familiar with the various matters introduced in this lesson by working practical examples.

VELOCITY RATIO AND FORCE RATIO OF MACHINES. MECHANICAL ADVANTAGE, ETC.

Let us now apply our law of work in the study of a few simple machines. It is scarcely necessary to give a definition of the term "machine"; everyone knows what is meant by the word. A machine is a collection of parts or elements working together, and by it energy is either transformed, or applied to a particular purpose. Looking at the matter from the point of view of *force*, a machine may enable us to exert a great force at a certain place, and in a particular direction, by the application of a comparatively small force to some portion of the machine.

The *velocity ratio* of a machine is the ratio of the velocity of this latter force as compared with that of the load. It is evident that if there were no friction and no storage of energy, all the energy given to the machine in the application of the motive force would be given out in lifting the load. Thus, if the applied force P act through r feet, whilst the load is raised 1 foot—the velocity ratio of the machine being therefore r to 1—$P \times r$ units of work are given to the machine, and $W \times 1$ units are obtained from it. On the supposition already made,

$$P \times r = W \times 1 \text{ or } \frac{P}{W} = \frac{1}{r},$$

And the *force ratio of a machine is the reciprocal of its velocity ratio*, if there is no friction.

The more slowly a force moves the greater is its amount, or as the old and somewhat inexact rule had it, "what is gained in power is lost in speed." The ratio of $\frac{W}{P}$ is very often called the *mechanical advantage* of a machine, expressing as a ratio the *advantage* in relation to force gained by the use of the machine. Now, if there were no friction, if in fact the machine were of that ideal kind described in the older books on mechanics, it is evident that the mechanical advantage would be the same, numerically, as the velocity ratio of the machine. It would also be constant, since the velocity ratio is, in most cases at least, constant, having reference merely to the relative sizes of certain parts of the machine. This we shall term the *hypothetical* mechanical advantage of the machine, as distinguished from the *real* mechanical advantage which, as we shall see presently, can only be obtained by experiment. With these preliminary statements consider a few single machines: first, on the

hypothesis of no friction; second, as the machine actually exists, taking friction into account.

THE INCLINED PLANE.

One of the simplest elements is the inclined plane, formerly much used in the raising of great

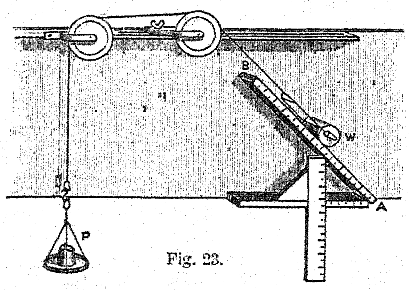


Fig. 23.

weights, and still employed in various ways in machines.

Let the weight W (Fig. 23) be drawn with a uniform velocity a distance l feet up the plane by a force P, as shown. Let h feet be the vertical height through which W is raised when it moves along l feet of the slope, then if there is no waste, and no storage of energy, the law of work tells us that

$$P \times l = W \times h$$
$$\text{or } \frac{W}{P} = \frac{l}{h}.$$

The mechanical advantage of the inclined plane is therefore the *ratio of its length to its height*, which, of course, is the same as the ratio of any length measured along the plane to the difference of level of the ends of this length.

In this case the force is applied parallel to the slope of the plane; but if it were applied parallel to the base of the plane, the rule would be $P \times b = W \times h$, since P would fall a distance equal to the *base* of the plane, whilst W is raised through the plane's vertical height, and hence the mechanical advantage $\frac{W}{P}$ would in this case be $\frac{\text{base of plane}}{\text{height}}$.

It is very easy for the student to arrange a simple piece of apparatus to illustrate roughly this law; but great difficulty will be experienced if it is desired to arrive exactly at the result here given, as friction can *not* be eliminated.

THE SCREW.

The screw may be regarded as an application of the principle of an inclined plane; the force usually acting parallel to the base of the plane. This will readily be seen if a piece of paper is cut to the shape of a right-angled triangle, and then wrapped round a cylinder, the base of the triangle being, say of the same length as the circumference of the cylinder, and placed parallel to one end of it.

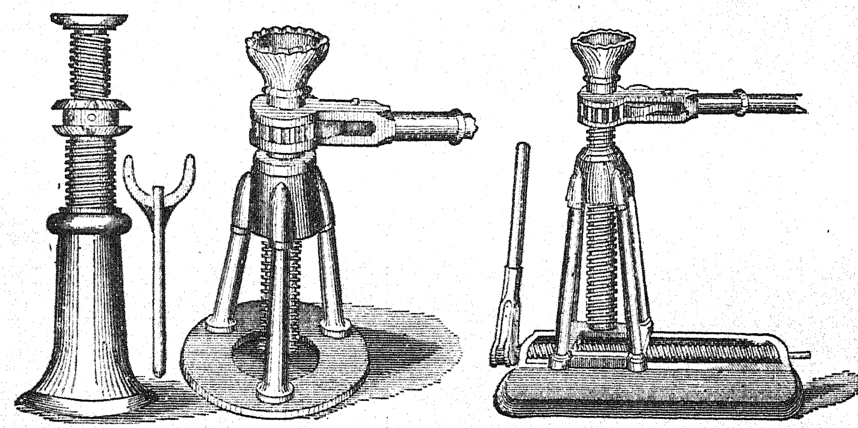


Fig. 24.

It is now evident that the sloping side, or hypothenuse of the triangle forms the outline of a screw surface, and the height of the triangle is the same as the *pitch* of the screw. We define *pitch* in this connection as the distance, measured axially, from the centre of one thread or convolution of the screw to the centre of the next, the screw being single-threaded. It is evident that this is also the distance by which the screw would move axially, if turned once round in its nut.

The different shapes and angles of screw-threads will be fully discussed in the lessons on Machine Construction. There are a great many applications of the screw in practice. The screw-jack, shown in Fig. 24, is often used for raising weights. Let the force P be applied at the end of the handle,

and let it raise steadily a weight W, then if P goes once round, the weight will be raised a distance equal to the pitch of the screw. Hence

P × circumference of circle which it describes = W × pitch of screw,

$$\text{or } \frac{W}{P} = \frac{\text{circumference of P's circle}}{\text{pitch of screw.}}$$

I need hardly point out that in all cases where a ratio is given both *terms* of the ratio, *i.e.*, the numerator and denominator of the fraction representing the ratio, must be expressed in the *same units* when a calculation is made.

ELECTRICAL ENGINEERING.—III.

By Edward A. O'Keeffe, B.E.
Senior Demonstrator in Electrical Engineering, City and Guilds of London Technical College, Finsbury.

[*Continued from p. 104.*]

THE DYNAMO (*continued*).

ELEMENTARY PRINCIPLES (*continued*).

The flowing of the current generates lines of force, and the converse proposition is also true, namely, the setting up of lines of force round a wire generates a current in it. If a loop of wire be moved from a distance close to the pole of a magnet, so as to allow a number of lines of force to pass through it, a current will be induced in the loop as long as the motion lasts, but will cease as soon as the loop has come to rest; if the loop be now withdrawn another current will be induced in it, but in the opposite direction to the previous one. In each case the induced current is in such a direction as to exert a magnetic force which tends to oppose the motion of the loop. The motion of the magnet up to, and from, the loop would have produced exactly similar effects. These currents are generated by the insertion and withdrawal of the lines of force from the loop. The mere fact of lines of force passing through the loop does not generate a current, however great the number may be; *it is the change in the number of such lines that gives rise to the current, whose strength is proportional to the rate at which the change takes place.*

Fig. 7 illustrates the case in which a loop of wire is situated in a uniform magnetic field, the uniformity of the field being denoted by the lines being at equal distances apart. If this loop, originally occupying the position marked 1, receives a motion of translation, so as to occupy position 2 or 3, there will be no current generated in it since the number of lines of force passing through it remains unaltered during the motion.

Fig. 8 illustrates the case in which a loop originally occupying position 1 in a field of variable strength receives a motion of translation so as to occupy position 2 or 3, and in either case a current is generated in it, whose direction is shown by the

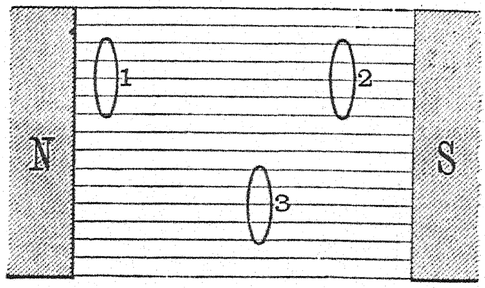


Fig. 7.

arrows. In both these cases the number of lines passing through the loop is diminished during the motion, and it is this diminution in the number of lines that sets up the E.M.F. and consequently the current in the conductor. If the loop originally occupied position 3, and was moved into position 2 or 1, it would also have currents generated in it,

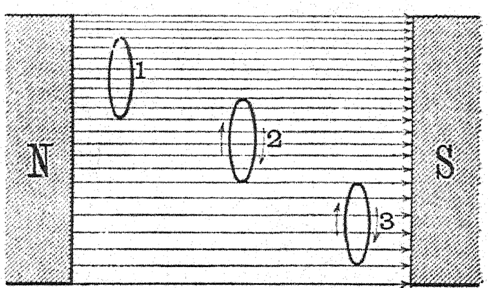


Fig. 8.

but these currents would flow in the opposite direction to that indicated by the arrows. The reason of the change of direction of the current is obvious when we consider that the number of lines passing through the loop during its motion is now being increased, whereas in the previous case it was being decreased.

Fig. 9 illustrates what happens when a loop originally occupying position 1 is made to rotate into positions 2, 3, 4, 5, 6, 7, and 8 successively in a field of uniform strength. From position 1 to 2 the number of lines passing through it is being diminished, and a current is therefore generated in it which flows as shown by the arrows; from position 2 to 3, the lines are still being diminished, and when in position 3 no lines are passing through, a current is therefore generated in the same direction as before. From 3 to 4 the lines are increasing, but as they are now passing through the opposite face of

the loop the current generated is still in the same direction as before; diminishing the number of lines passing through one face of the loop has therefore the same effect as increasing the number passing

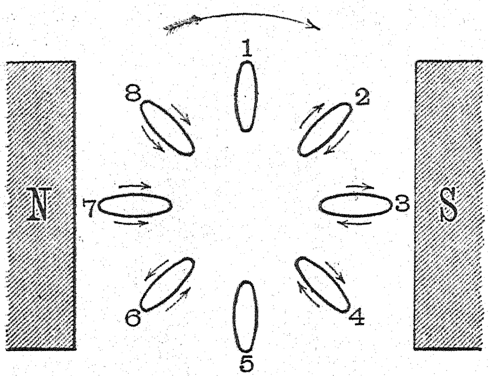


Fig. 9.

through the other face—both operations tend to generate a current in the same direction in the loop. From 4 to 5 the lines are still increasing, and on reaching 5 they are at a maximum. From position 1 all the way round to 5 the current is therefore generated in the same direction in the loop. From 5 to 6 the lines are diminishing, and therefore the current is generated in the opposite direction in the loop, and the same action continues from position 6 to 7; at position 7 there are no lines passing through, but from 7 to 8, and from 8 to 1 the lines are increasing, but are passing through the opposite face. From position 5, right round to position 1, the current is therefore generated in the same direction in the loop, and this is the opposite direction to that in which it was generated while passing from 1 to 5.

In Fig. 9, if instead of considering a single loop of wire moved into different positions in a magnetic field, we consider a continuous circular spiral, we shall find a very similar state of things happening. Such a spiral is shown in Fig. 10. It is supposed to be mounted on the axis O, and to be turning in a clockwise direction in the magnetic field round that axis. In every loop of this spiral it is clear that an E.M.F., and consequently a current, is being generated, and it is equally clear from Fig. 9 that in the right-hand half of this spiral all E.M.F's. tend to drive currents in the same or downward direction; also, in the left-hand side of the spiral, all the E.M.F's. tend to drive currents in the same or downward direction, and that these currents meet at the lowermost point of the spiral. If both the lowest and highest points of the spiral make a sliding contact with two conductors b and b_1 which form the terminals of a complete external circuit, a current will flow out of the spiral through b, through the external circuit and back to the spiral through b_1. This arrangement, shown in Fig. 10, is really a dynamo of the Gramme type. The magnets N and S which give rise to the magnetic field are called the *field-magnets*, and may be either permanent steel or electro magnets; the rotating series of loops is the *armature*, and in this particular form it is known as a *ring* armature; and the sliding conductors b and b_1 which carry off the current from the armature are the *brushes*. In dynamo practice the loops of wire are invariably wound on an iron ring, which, besides making the arrangement a sound job from the mechanical engineer's point of view, has also a most important bearing on the electrical side of the question. The substitution of iron for air, or any other non-magnetic substance, as the core of the spiral has the effect *of enormously increasing the number of lines of force that pass through the loops.* Where the number of lines passing through the loops

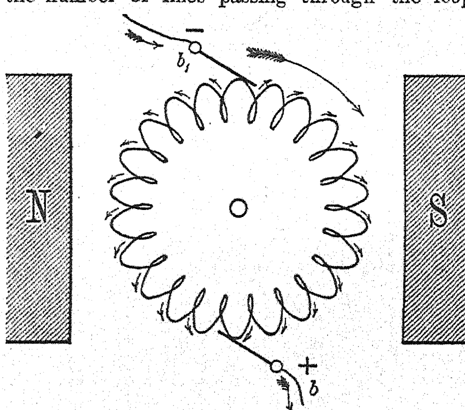


Fig. 10.

might in Fig. 10 be counted by hundreds, the insertion of an iron core would increase this number to thousands or tens of thousands. The effect of the iron is to multiply the number of lines which pass through the spaces.

Increasing the number of lines passing through the loop at a definite rate produces exactly the same strength of current as would be produced by decreasing them at the same rate, but the two currents are in opposite directions. The strength of the induced current is proportional to the rate at which the number of lines of force passing through the loop is changed, or, as it is more usually expressed, upon *the rate at which the lines are cut*; a strong current can therefore be produced either by increasing the strength of the field—that is to say,

by having a larger number of lines per unit area, or by increasing the area and the speed of the loop. It is, however, impossible to have a field whose strength is beyond a definite amount—as will subsequently be pointed out—while purely mechanical considerations limit the speed and the area of the loop. If, instead of using a single loop, the wire had been wound into a coil of many turns, the E.M.F. induced in it would have been proportional to the number of those turns. The increased E.M.F. thus obtained would not produce a corresponding increase in current, since the increased length of the wire would introduce an additional resistance into the circuit. The induced E.M.F. is therefore proportional to three things, namely, *the number of turns of wire on the coil, the number of lines of force cut, and the rate at which the cutting occurs*, or, expressing it in symbols—

$$E \propto b \times s \times N,$$

where b expresses the number of loops of wire of which the coil is made up;
" n " speed of the coil; or, the number of times the lines are cut per second;
" N " the total number of lines of force passing through the coil from one side to the other;
" E " total induced E.M.F.

In order that this formula shall be available in a practical form, it now becomes necessary to refer to the units which are used in practice. *When a loop cuts lines of force at the rate of one line per second, there will be unit electromotive force generated in it.* This unit E.M.F. is expressed in the C.G.S. (centimetre-gramme-second) system of units. This system of units will be dealt with in detail in a later chapter, for our present purpose it is sufficient to know that there are 100,000,000 C.G.S. units of E.M.F. in one volt, and therefore the above formula becomes

$$E \text{ (in volts)} = \frac{n\,b\,N}{100{,}000{,}000}$$

or, as it is more usual to write it,

$$E = n\,b\,N \times 10^{-8}$$

We can therefore calculate the E.M.F. in volts generated in any circuit when we know the strength of the field, the number of loops, and the speed.

One of the earliest types of dynamos, and one which most clearly shows the manner in which the principles just laid down are utilised in practice, is the Pixii machine.

Fig. 11 illustrates the principle of this machine. S N is a powerful horse-shoe magnet, with its poles pointing vertically upwards, and capable of rotating about a vertical axis passing through its central point. Above this magnet are fixed two coils of wire, $p\,p'$, wound on heavy soft iron cores, a and b, which are joined at the top by an iron yoke. Let us consider what happens when the north pole, N, is approaching the core a at the same time that

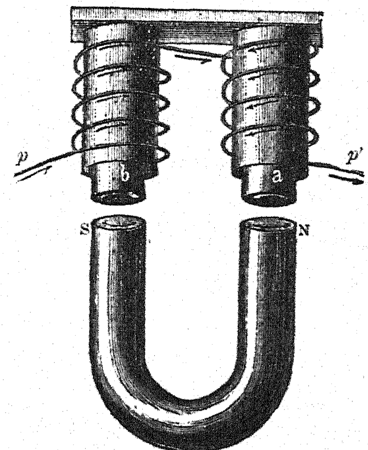


Fig. 11.—Principle of the Pixii Machine.

the south pole, S, is approaching the core b. The pole N, on its approach, will send through the core a a continually increasing number of lines of force, which will be cut by the coil, and which will therefore induce a current in that coil whose direction will be such as will tend to oppose the motion; that is to say, a current will be induced in the coil in such a direction as will convert it into a north pole, which will repel the approaching north pole. The direction of this current is, according to the Ampèrian rule, in a counter-clockwise direction—as viewed from the pole—as is indicated by the arrow-heads on the wire. The same line of argument shows us that the other coil will be temporarily converted into a south pole, with the induced current circulating round it in a clockwise direction, as shown by the arrow-heads. As the coils are wound in opposite directions on the two cores, these induced currents flow through the wire in the same direction, coming out at the point p', flowing through the external circuit, and returning at the point p. When the poles of the magnet have come opposite to the ends of the cores, the maximum number of lines of force is passing through the coils, and therefore any further rotation of the magnet begins to withdraw the lines.

This withdrawing of lines of force from the coils generates currents in the opposite directions to those in which they previously flowed, and hence the

core *a* will be converted into a south and *b* into a north pole. These temporary poles will now exert forces of attraction on the receding poles of the revolving permanent magnet, and the mechanical energy which must be expended in maintaining its rotation against these forces is the equivalent of the electrical energy generated in the coils. In this machine the direction S of the current in the coils is reversed each time the poles of the magnet pass beneath the ends of the cores *a* and *b*; that is to say, the current in the circuit is reversed twice during each complete revolution of the magnet. Such a current is usually known as an *alternating current*, and the machine as an *alternate-current dynamo*. It is possible, however, by the addition of a *commutator* to make all these currents flow in the same direction through the external circuit, and when this is done the machine is known as a *continuous-current dynamo*.

The commutator devised by Pixii and used by him in his machine is illustrated in Fig. 12.

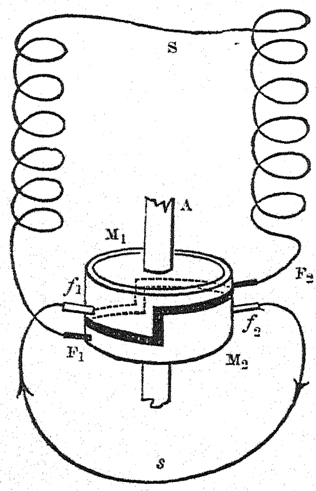


Fig. 12.—PIXII'S COMMUTATOR.

It consists of a short brass tube, mounted on the same shaft, A, as the rotating magnet, and cut into two portions, M_1 and M_2, which are carefully insulated from each other, as is indicated by the thick black band shown between them. This insulating substance usually consists in modern dynamos of mica. The ends of the wire marked S, which is the armature coil, rest one on each part of this commutator at the points F_1 and F_2, by means of flexible metallic brushes. The ends of the external circuit *s* also rest, by means of similar brushes, on the commutator at the points f_1 and f_2. The current, as shown, is flowing into the external circuit at the point f_2, to which it gets through the section M_2 of the commutator from the point F_1, where it leaves the coil; this current returns to the coil through f_1, M_1, and F_2. As the magnet and commutator rotate—the brushes being stationary—the current is reversed at the instant that the brushes, f_1 and f_2, pass from one section of the commutator to the other. This reversal of the current's direction evidently occurs when the poles of the magnet pass beneath the cores of the coils. If the current had been continuous in the coil, this changing of the external brushes on the commutator would naturally change the direction of the current in the external circuit; but as the direction of the current in the coil is changed at

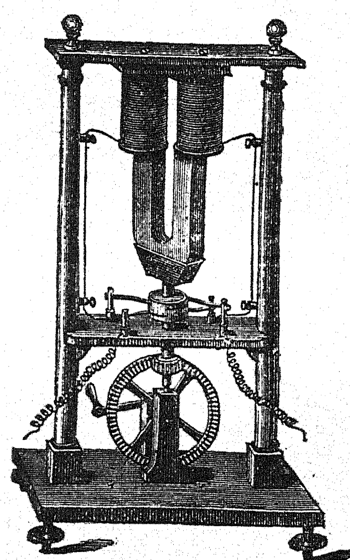


Fig. 13.—PIXII'S MACHINE.

the same instant, its direction through the external circuit is maintained constant.

The complete machine is illustrated in Fig. 13, where it is seen that the magnet is made to rotate by turning the large wheel below.

SIEMENS' SHUTTLE-WOUND ARMATURE—THE DRUM ARMATURE.

In 1867 Siemens brought out what is known as his shuttle-wound armature, which was a decided advance on anything that had preceded it. Fig. 14 shows the manner in which the armature is wound, as well as its position between the poles of the field-magnets marked N N and S S. The frame of the armature is an iron core, of the shape shown in the upper part of the diagram, and is mounted

on the axis, A X. A single turn of wire is shown wound in position on this core, and this winding is continued till the gap in the core is completely filled up, and further, till the armature has assumed a circular form. The increased number of turns of wire simply add to the E.M.F.; the study of what takes place in a single turn will suffice for all. On the shaft that carries the armature are situated two insulated brass rings, at the points marked A and M, which act as the collectors, and on these rest the metallic brushes, 1 and 2, through which the current is transmitted to the external circuit. One end of the wire on the armature is connected to the ring, M, whilst the other end is connected to the ring A. The north pole of the field-magnet is marked N N, and the south pole, S; the large arrow-head indicates the direction in which the armature is supposed to be rotating.

Lines of force pass through the armature in going from the pole N N to the pole S, and the cutting of these lines by the coils generates currents, whose direction can be determined by the rule already given. In the position of the armature shown in the upper figure, one flange of the armature core is approaching the north pole of the field-magnet, whilst the other is approaching the south pole, and lines of force pass through and magnetise it, converting the flange near N N into a south pole, and the flange near S into a north pole. This polarity is indicated on the armature by the letters *s s* and *n n*. The direction of the current induced by the insertion of these lines through the coil must be such as will produce a force tending to stop the motion of the armature. The direction of the current through the coil which will produce this effect is shown by the small arrow-heads on the coil, as well as the arrow-heads, *c* and *d*, on the wires of the external circuit. The coil is shown in the position where it is leaving the north pole and approaching the south pole, and the current in it exercises, according to Lenz's law, a force of attraction on the pole which it is about to leave, which force clearly tends to stop the motion of the armature. In the lower portion of the diagram, the armature is shown after having passed through half a revolution; and it will be seen by the arrow-heads that though the current flows in the same direction relative to the field-magnets—which it invariably does—it passes in the opposite direction through the coil.

In the upper diagram the current flows into the external circuit through the brush marked 1; while in the lower diagram—after the coil has passed through half a revolution—the current flows from the terminal 2. Between these two positions of the armature there must be a certain point at which no current is being generated, which implies that the coils are cutting no lines of force. The cycle of changes through which the current passes is as follows:—Starting at zero, it rises to a maximum at the end of the first quarter of a revolution, and returns to zero at the end of half a revolution; it then increases to a maximum in the negative direction at the end of the third quarter, and returns to zero at the end of the fourth. It will thus be seen that the current generated by this machine is not only intermittent in its action, but is also alternating in its direction.

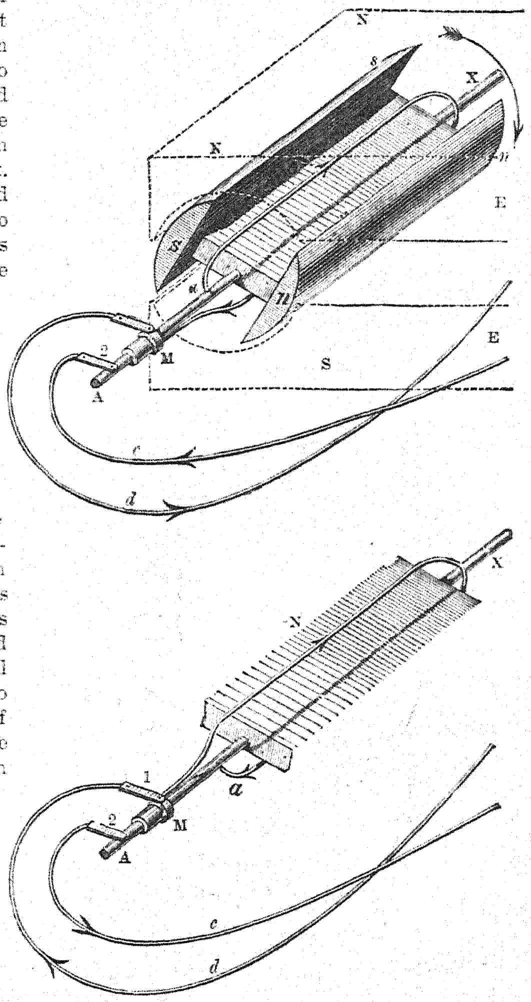


Fig. 14.—Siemens' Shuttle-Wound Armature.

TECHNICAL EDUCATION:

ABROAD.

By Sir Philip Magnus.

Into the origin of technical schools abroad the space at our command does not enable us to enter. The succession of improvements made in this country in the application of steam power to manufacturing industry enabled us for many years to maintain a position of supremacy in engineering and many other trades. The change brought about by the gradual conversion of handicrafts into manufactures gave us at first a great advantage over our foreign neighbours, owing partly to our native inventive skill, but mainly to the range and extent of our coal and iron fields. In many departments of industry our foreign neighbours were left far behind us, and very naturally they considered the best means of attracting to themselves some of the trade which was then so briskly carried on in this country. In natural resources they were deficient; and in order, therefore, to foster the growth of industry in their own country, it was necessary to practise the most rigid economy in the use of materials, and to bring to bear the highest skill and intelligence in the processes of production. At first, they availed themselves largely of the experience we had acquired by sending to this country some of their best artisans to learn our methods in our own workshops; and in order to give time for the growth and development of their new manufactures, they imposed protective duties on most foreign imports. Owing probably to the very disadvantages under which they started, they recognised much sooner than we did that trade and commerce were professions with a theoretical as well as a practical side, analogous in many respects to medicine and jurisprudence, and that the theory, at least, could be taught in schools similar to those in which physicians and lawyers received their academic training. This was a great step in advance. They saw, that underlying the practice of trade and commerce is a knowledge of the principles of various branches of science, and that the teaching of these principles, in their application to manufacturing and commercial purposes, could be efficiently and advantageously conducted in schools specially organised and equipped. We, in this country, have now reached the same conclusion. But it was not till the publication, in 1884, of the results of the inquiry of the Royal Commission on Technical Instruction that the extent of the influence of school teaching on the successful development of trade was fully understood and recognised.

In considering foreign systems of technical instruction certain general principles may be noted, which are probably of wider interest than the description of special institutions, and of the purposes they severally serve. What first strikes the inquirer, in visiting technical schools abroad, is the close connection between technical and general education. When the subject of technical education was first brought prominently under the notice of the people of this country, it was thought that technical education was a means of teaching particular trades, and was intended to take the place of apprenticeship and workshop practice. To a very limited extent, and under certain conditions, this is doubtless the case. But abroad one soon sees, that technical instruction does not mean a distinct or new kind of teaching, but rather the adaptation of the general instruction given in schools and colleges to the requirements of new occupations. The fact, that the methods of production and distribution, in which the great majority of the working population of a country are necessarily engaged, have during the last half-century undergone a very considerable change, has necessitated a corresponding change in the character of school instruction; and it is rather in the form of instruction than in any special teaching that the advance in technical education abroad shows itself.

Another matter of general application worth noting is, that the problem of technical education may be approached from the position of the masters or from that of the workmen. In Germany, greater attention has been given to the higher education—to the training of the officers of the industrial army; in France, on the other hand, whilst the higher training has been by no means neglected, the technical education of the artisan has been chiefly considered, and provided for. Thus France is the home of the apprenticeship school, and Germany of the technical university. Much is to be said as to the paramount importance of giving the highest possible training to the masters of industrial concerns, and such general education only to the operatives, as shall enable them intelligently to obey orders, and to carry out the instructions of their chiefs. On the other hand, it is recognised that superior skill in artifice, and the more general avoidance of error in manufacturing industry, are shown when the workmen possess some knowledge of the principles and details of the work in which they are engaged; whilst from the workman's point of view, and having regard to his interests and advancement, this special knowledge is of the utmost importance. We, in England, are endeavouring to combine both systems. We recognise that in some industries, requiring for their successful development the application of the

highest scientific knowledge, the technical instruction of the masters and managers is most needed; whilst, in others, the careful training of the artisan, which can only be obtained in a special school, is equally essential.

The most rapid survey of technical instruction abroad shows us, that no one system can be pronounced the best, but that the methods of teaching and of school organisation must be adapted to the genius and habits of the people, to the climatic and other conditions under which they live, and generally to the purposes which the education is intended to serve. It must also have a distinct reference to the pre-existing system of education, which may be modified, but cannot be wholly transformed, to suit the wants and requirements of new industrial developments.

Germany and France are certainly the most interesting countries in which to study the problem of technical education. In Germany, till very recently, the main object of technical instruction has been the training of masters and managers, of those who direct engineering or manufacturing works; and in the methods and results of such training the Germans have been most successful. The institutions in which this education is provided were formerly called polytechnics, but are now generally known as technical high schools, the term *Hochschule* being synonymous with university. Of such institutions there are seven in Germany besides those in Vienna and in other parts of the Austrian Empire. Of these the largest and most important is the one recently erected in Charlottenburg—the fashionable suburb of Berlin. It corresponds in its general character with the City and Guilds Central Institution at South Kensington, but is many times as large, and has been erected and is maintained at a much greater cost. Some idea of the comparative size of these institutions may be gathered from the fact that the City and Guilds Central Institution was intended for about 200 students, and the cost of erection and equipment was about £100,000. The Berlin Institution has accommodation for 2,000 students, and the number in attendance is over 1,500, whilst the cost of erecting the main building, which does not include the chemical laboratories, exceeded £400,000. The courses of instruction embrace the five faculties of architecture, civil engineering, mechanical engineering, chemistry and metallurgy, and general science. The teaching staff of all grades numbers eighty-six professors and lecturers and twenty private tutors. Every department of science bearing upon constructive or productive industry is represented by a specialist. It must not, however, be supposed that the purpose of such institutions is to train students in the details of any particular profession. The instruction is practical in so far as the teaching of science is necessarily practical, but it is also theoretical, and its main object is the elucidation of principles, and the promotion of scientific research in connection with industrial problems. The methods of teaching adopted in these technical institutions do not appreciably differ from those pursued in the universities, and the question has been seriously discussed whether there is any real advantage in separating such institutions from the universities. Indeed, in the chemical faculty their functions cannot be easily distinguished; and the laboratories of the university have contributed to the progress of industry as many useful men and as valuable results as the laboratories of the polytechnic. To the facilities for higher scientific education, which are provided in the universities and polytechnics, the Germans owe much of their industrial success; and although the expenditure has been large, and judged by our own standard, somewhat wasteful, the commercial results realised have been fully commensurate.

In Germany, students enter the polytechnic at about 19 years of age, after completing their course of study in a gymnasium or *Realschule*. In these schools the curriculum does not embrace any studies of a strictly technical character. In the gymnasium it is mainly classical, and in the *real* (or modern) school the course of study is very similar to that of the modern side of one of our large public schools. It is thought that the best preparation for the higher technical pursuits is found in the systematic study of Latin, mathematics, and elementary science, supplemented by a thorough training in the grammar and literature of modern languages. The school fees are so low that a large proportion of the people are enabled to obtain the best secondary education, and there is consequently no lack of well trained youths who are able to take advantage of the facilities offered by the State for higher education. Although the polytechnic or technical high school is undoubtedly the most prominent feature in the German system of technical education, there are other schools, of a more special character, providing instruction adapted to the varied wants of the industrial population. Among these, mention must be made of the weaving and building trade schools. To the weaving schools at Chemnitz and Crefeld, Germany owes much of its success in the manufacture of textiles. The weaving school of Chemnitz was founded as early as 1856. Land was given by the town, and the building was erected by the municipality. The teaching in this school is thoroughly practical. The students commence by working at

the hand-loom, and when they are able to use it without assistance, and understand how to weave, they pass to the power-loom. The school is provided with a large number of different looms, on which the most varied texile fabrics are woven. The school is attended by the sons of merchants and manufacturers, and by future foremen and overseers. In this branch of industry, as in engineering, the most efficient instruction is provided for the masters and managers of works. In Chemnitz, and in other weaving districts, there are evening and Sunday schools for those who are unable to give up any portion of the day to technical instruction. Mr. Felkin, in a little book, published in the year 1881 by the City and Guilds Institute, was the first to call attention to the organised system of technical instruction provided in Chemnitz for all classes of producers and distributors, and it was he who first showed the extent to which the trade of Saxony had benefited by this provision of efficient schools.

Crefeld possesses one of the best equipped of modern textile schools. It was opened in December, 1883. The building was erected at a cost of £42,500, and comprises departments for weaving, dyeing, and finishing. The school contains looms for every variety of textile fabric, and is rich in appliances for instruction in the several processes connected with the manufacture, dyeing, and finishing of different kinds of cloth. To the influence of this school is justly ascribed the large export trade of Germany in silks and velvets. The fees are low, but candidates for admission to the dyeing department are required to be conversant with the fundamental principles of chemistry and physics. The day students are mostly sons of manufacturers, but the school is open on Sundays, when it is largely attended by workpeople. The annual cost of the maintenance of the school is £5,300, which is met by the students' fees and by contributions from the State and the town.

Weaving and dyeing schools are found in other parts of Germany, but none can compare in the completeness of their arrangements and fittings with the school at Crefeld.

Of other special schools in Germany, the most interesting and most widely distributed are the building trade schools. These are generally open in the winter months only, when building operations are for the most part suspended. They are found in nearly all the large towns of Germany, but the school at Stuttgart is perhaps the most characteristic. The instruction is intended to supplement the trade work in which the students are generally engaged. It is mainly theoretical, and includes very little manual training. The aim of the instructors is to teach the scientific principles underlying, and associated with, the practice of the trade, rather than the practice itself. Of all the special schools the weaving and dyeing schools are the most practical. In the building trade schools, which are generally housed in costly buildings specially erected for the purpose, the instruction embraces languages, mathematics, bookkeeping, geometry, drawing, building construction, machine construction, surveying, and mensuration. School fees are charged which, although by no means high, are sufficient to indicate that the teaching is intended for future foremen and the better class of artisan rather than for the labourer or unskilled workman. Besides these, there are schools for the mining and metal-working industries, and for other trades; but the instruction is very little specialised, and is in nearly all cases supplementary only to workshop practice.

Another very interesting type of school found in Germany is the applied art school. Whilst the instruction given in nearly all the technical schools of Germany is limited to geometrical drawing, and to the principles of science in their application to the parent industries, the teaching in the industrial art schools approaches more nearly to workshop training. In this respect the system of technical teaching, as applied to art industries, contrasts with that adopted in connection with trades involving the application of scientific principles, and differs from the French methods of instruction, in which the distinction between pure art and applied art is much less clearly marked. The *Kunstgewerbeschulen* of Germany are not merely schools of design. They are institutions in which separate art processes are also taught. They have departments for wood carving and wood sculpture, for metal casting and metal chasing, for glass staining, pottery painting, house decoration, and for the practice of other trades.

The instruction, although essentially practical, is much more than mere trade teaching. It embraces painting in all its branches, modelling, anatomy, geometrical drawing, perspective, the principles of design, and the history and literature of art. Frequently, the schools are closely connected with the Industrial Art Museum, where the students have the opportunity of seeing the best models and specimens of work.

The system of technical instruction in Austria does not differ materially from that of Germany. The schools are similarly organised. The Polytechnic, the Applied Art School, and the Weaving School of Vienna are very similar to the corresponding institutions in Berlin. But besides these, there exist, scattered throughout the provinces of Austria, trade schools in which is taught some

special industry. Most of these schools are situated in the small towns and rural districts, and the trade teaching is combined with instruction in general subjects. They form continuation schools in which the pupil acquires dexterity in some particular handicraft. They are known as *Fachschulen*. They are widely distributed throughout the empire, and are under State control and supervision. Among the special subjects taught are carpentry and joinery, wood carving, marquetry, silver filigree work, marble work, photography, and printing processes. In Bavaria and in other parts of Germany, similar schools are found in which clock making, straw plaiting, basket making, pottery painting, and various other industries are taught. Some idea of the aim and character of the teaching given in these schools may be gathered from the remarks of one of the instructors. He told the Commissioners who visited his school in 1883 that "he aimed at making his pupils thoroughly conversant with the nature and properties of the material with which they had to deal. They should learn all that could be said of the growth or formation, construction and strength, and the history and various uses of the materials with which they had to work. They should be able to draw or model accurately whatever they have to make, and they should be well acquainted with the most recent mechanical appliances for dealing with or preparing the materials for their trade."

In Switzerland the system of technical education is more or less similar to that of Germany. Nowhere is education more generally diffused, or of a higher standard, than in Switzerland. The prosperous manufactures of Switzerland are a standing evidence of the economy of a large and wise expenditure on education, by which the advantages of the highest teaching are brought within reach of all classes of the community. So much has been said and written on Swiss education that it is only necessary to repeat, that nowhere are the elementary schools more completely equipped or better organised, that the instruction is gratuitous, and that there is an excellent system of secondary schools leading to the universities on one hand and to the Federal Polytechnic of Zurich on the other. The Polytechnic of Zurich, which is modelled on the type of similar schools in Germany, is one of the finest institutions of its kind in Europe. It was established in 1854, and has since then been frequently enlarged. It consists now of five separate buildings. The main building was opened in 1865, and cost £72,000, and the observatory, which was erected in 1874, cost £10,000. The chemical laboratory was projected when the Commissioners visited Zurich in 1882, and has since been completed at a cost of £52,000 for the building and £16,000 for the fittings and apparatus. As recently as 1891 a new physical laboratory has been erected at a cost of £48,000 for the building and £20,000 for the fittings. The yearly expenditure on maintenance is £26,000, towards which the State contributes £22,480. These figures give some idea of the magnificent scale on which this Palace of Science is conducted. The Swiss people have reason to believe that the money has been usefully and, from a commercial standpoint, economically expended. In natural resources one of the poorest countries, with a small and scattered population, Switzerland has succeeded in founding important industries and in establishing large manufactures. Many of her engineering works are of considerable magnitude, and from her coal-tar colour works a large export trade is carried on in artificial colouring matters. Nowhere is the influence of the polytechnic training so remarkably shown as in the aniline colour factories of Switzerland and Germany. Here, the research work of the school laboratory is pursued on a far more extensive scale and with a view to commercial results. Every factory contains a number of well-equipped laboratories, presided over by a staff of eminent chemists and their assistants, all of whom have received a special technical training. In these laboratories, continuous experiments are carried on for the purpose of effecting improvements in the processes of manufacture. The chemists engaged in these works have not all been trained in the polytechnic schools. Many come from the universities, of which there are already five in Switzerland, whilst a new one is about to be erected in Fribourg.

In their engineering works the results of the higher scientific training are no less evident. Lacking cheap coal for fuel, the Swiss have been enabled, by improvements in the construction of turbines and in the modes of transmitting power, to utilise their streams and mountain torrents and to prepare the way for an extensive use of water power both for the purposes of electric lighting and for driving machinery. Although the industrial prosperity of the Swiss must be mainly ascribed to their excellent system of primary and secondary schools and to their institutions for the higher scientific training, other schools intended mainly for the preparation of foremen are not wanting. Of these the principal is the Technicum of Winterthur. Weaving schools and schools of applied art are also found in different parts of Switzerland, similar to those of Germany, to which reference has already been made.

In France, the system of technical education presents many points of contrast to that of

Germany and Switzerland. The problem appears to have been approached rather from the position of the artisan, and the most striking features are the handicraft training in the elementary schools, the practical trade work in the apprenticeship and foremen's schools, and the abundant and excellent facilities provided by the State for the highest instruction in pure and applied art. It is difficult to give an idea of technical education in France without considering the entire system of school organisation, because, except in certain subjects, there is a very close connection between ordinary and professional instruction. Indeed, the influence of the teachings of Rousseau is felt in all grades of schools, and nowhere is seen so close a relationship between school training and the actual work of every-day life as in the French system of primary and secondary schools. Beginning with the infants, we find in Paris and in other parts of France a number of schools known as *Écoles maternelles.* These had their origin in certain charitable institutions known as *Salles d'asile*, where mothers, who had to earn their living, could leave their children during work hours. In 1881 these institutions were placed under State control and their name was changed to *Écoles maternelles.* Infants are admitted to these schools between the ages of two and seven. Their instruction consists of such elementary notions of morality, and of reading, writing, and reckoning, as can be imparted to children of so tender an age; of exercises in manual training, and of lessons in singing and bodily movements. The main feature of the teaching is the use of objects instead of books; of things rather than words. In these schools the child acquires his first experience in directed manual exercises, intended to lead up to that adroitness and skill in which the French artisan has long been distinguished. The school hours are long, but the child is not wearied, as the admirable system of Fröbel, by which the child's natural activity is encouraged and developed, is wisely and usefully adopted. The school opens at 6.30 a.m. in summer and at 7 in winter, and the children are dismissed any time between 4 and 6 p.m. at which their parents can call or send for them.

From the maternal school the child proceeds to the primary school, which is the true foundation of a Frenchman's education. The striking feature of the French system of primary education is its continuity. The instruction given in one school is designed to lead up to that of a higher grade. Thus a child on entering the ordinary primary school is supposed to have received the training provided in the *École maternelle.* He may have received it at home under the guidance of intelligent parents, but he is expected to have had some systematic training. The primary school consists of four divisions:—(1) the infantine, (2) the elementary, (3) the middle, and (4) the superior. The infantine division is intended to connect the purely kindergarten method with the severer discipline of the elementary school proper. In the elementary course, the child is instructed in the rudiments of geography and grammar and in the method of history; he also learns, by means of object lessons, the first principles of physical science and drawing. In the middle course, which occupies two years and carries on the child to his eleventh year, the teaching is more specialised, including the geography and elementary history of France, geometry, and the ordinary subjects of an elementary education. The superior course also occupies two years, and brings the child to his thirteenth year, the age of exemption from further school attendance. During this period the child receives systematic teaching in the elements of chemistry and physics; he continues his drawing instruction; and by working always from natural objects learns the elements of design, and commences practical woodwork. It is to M. Salicis, who perseveringly demonstrated, at the well-known *École de la Rue Tournefort*, the advantages of manual training, that the development of such teaching in France, Belgium, and England, and in the United States is largely due. It now forms part of the instruction of all the elementary schools of Paris, and the general extension of the teaching is likely to lead to greatly improved methods. No trade is attempted to be taught in the French primary schools; but the children of France receive in these schools sound practical instruction, preparatory to the business of life. From the earliest age they are trained to the study of nature, and their faculties of observation are carefully cultivated by exercises of hand and eye and ear which produce in their minds a valuable store of sense-impressions.

The work of the primary schools is advanced in the higher elementary schools, which are an important feature in French education. These schools consist generally of two sides, one for commercial and the other for technical studies. They contain chemical and physical laboratories, carpentry and fitters' shops; and in some of the schools the instruction is specialised with a view to the particular trades of the district. They constitute middle schools of a type much needed in this country, bridging the way between the primary school and the technical university. Besides these superior primary schools, which are found in all the large towns of France, there are special engineering schools for the training of foremen. These are located at Châlons, Aix, Angers, and Nevers. In

the well-equipped school workshops, orders are executed for the Government. The students work for six hours a day in the shops and for about five and a half hours in the class rooms. The men trained in these institutions are found in nearly all the large engineering works of France. These institutions are known as *Écoles des Arts et Métiers*, and form together with the weaving and dyeing schools the principal technical colleges for the training of the better class of workmen and of foremen. Besides these schools, there are special schools for horology, and most of the large towns have technical institutions somewhat similar to our university colleges. The central school for the training of professional engineers and industrial chemists is in Paris, the constitution of which is somewhat similar to that of a German polytechnic.

To complete our notice of the facilities provided for technical education in France, it is necessary to refer to the abundant evening classes, in which lectures are given on the technology of different trades, and in which industrial drawing and art in all its branches are well taught. The evening instruction in France is conducted by a staff of eminent professors, whose qualifications for teaching are very superior to those of the ordinary science teachers in this country. The art schools throughout France are excellent, and instruction is very generally given in modelling and in painting from life, particularly from the nude. In connection with most of the art schools are found industrial museums, the opening of which on Sundays and holidays is proved to be of great advantage to the artisan and labouring population. Nothing, perhaps, has done more to educate the taste of French workpeople than the opportunities they have had to visit in their intervals of leisure these museums.

The systems of industrial education in other parts of Europe have much in common with those of France and Germany. In Belgium and Holland, manual training forms part of the elementary school course. The University of Louvain has special schools of engineering, and at Liége and Ghent are found excellent evening courses of instruction for artisans. The school of art at Antwerp and the commercial academy in the same city have acquired a European reputation. In Holland, the polytechnic at Delft is organised on similar lines to the polytechnic institutions of Germany and Switzerland, all of which it is needless to say are very different in their objects and character from the institutions bearing the same name which have been recently established in London. Italy is not far behind other countries in its provision for technical education. All its higher elementary schools are called technical schools, as indicating the industrial character of the teaching. But the education given in these schools is distinctly of a lower standard than that provided in the similar schools of France. Each district is furnished with a technical institute, which has departments for the study of engineering, naval architecture, applied chemistry, agriculture, builders' work, and weaving, according to the requirements of the district. These schools are fairly well attended, but are poorly equipped with modern apparatus, and there is an absence of public interest in their development. They are insufficiently supported, and are now somewhat antiquated. The higher technical institutes of Milan and Turin, which correspond to some extent with the German polytechnics, are more efficient, and are the principal training schools for engineers. Owing largely to the teaching of these establishments the subject of electricity in its applications to lighting and the transmission of power has made great advances in Italy.

Of Russian education very little can be said, but the technical school at Moscow is an institution of a high order of merit.

It is, however, in the United States that the greatest progress has been made during the last few years in the foundation of various grades of technical schools. But the most cursory consideration of this part of the subject would occupy far more space than can be here devoted to it.

PLUMBING.—IV.

By a Practical Plumber.

(*Continued from p. 137.*)

JOINT MAKING (*continued*).

Rust Joints.—This is another method of making a sound connection between cast-iron pipes, and is preferred by some to either rubber or yarn packing. It is made by mixing fine iron borings with water in which has been dissolved a small quantity of sal-ammoniac; it is mixed to a thick paste and packed between the joint and rammed tight with a caulking tool; it sets hard in a day, and has this merit, that if it leaks a little it will soon rust itself up. Care must be taken not to put too much sal-ammoniac, an ounce is quite enough for 7 lb. of borings. If too much is put, it is highly probable that it will cause sufficient expansion of the cement when setting to burst the socket. These joints are very secure and lasting.

Comparison of Soldered Joints.—Plumbers who *can* make good wiped joints as a rule are very much against copper-bit work, wiping almost everything regardless of cost, suitability, or anything

else except their own reputation as joint-makers. Some men will argue that under all circumstances a wiped joint is superior to that made by a copper bit. Others (mostly those who cannot do much at wiping) contend that a well-made blown or copper-bit joint is equal to any plumbers' joint that ever was made. I do not intend to argue in any dogmatic style in support of either of their views: like the men who quarrelled over the colour of the chameleon, they both may be right or wrong according to circumstances. Looked at in a reasonable light, a joint made in, say, ¾- or 1-inch pipe, in which both pipes have been carefully fitted and well sweated together, is, and must be, stronger at the joint than anywhere else, and if pressure were put upon it, it would burst anywhere except at the joint. What more is wanted? Certainly as regards actual strength the wiped joint properly made is superior, and it has the advantage of being able to be made in positions where copper-bit or blowpipe work is impracticable. But copper-bit work has its uses: for soldering small unions, caps and linings, bosses, small taps, washers, and wastes, and many other jobs, it is preferable to wiping. Moreover, in repairing jobs the quickness with which a joint or two can be blown or copper-bit soldered compared with the trouble, fuss, and expense of wiped joints make a considerable difference in the cost of a job. No doubt it looks better and more like plumbers' jobs to see two or three plump round joints, nicely set off with their soiling, than the humble and almost unobservable copper-bit joint. But if the householder has to pay 10s. 6d.

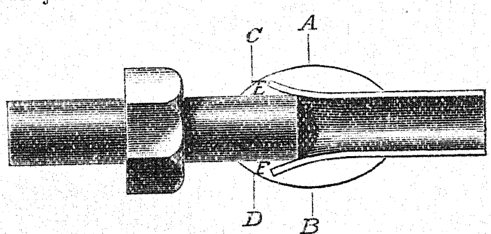


Fig. 45.

for it instead of perhaps 4s. or 5s., he is apt to be dissatisfied, and not without reason when the work could have been done at no sacrifice of efficiency at a considerably less cost. For soil pipes it is certainly best to always wipe the joints, the body of metal round them serving to strengthen them and also to preserve their shape. I have said that for soldering unions, bosses, etc., the copper-bit joint is preferable. The reason is this: these fittings are very short, and in wiping a joint between one of these and a piece of lead pipe the thick part of the wiping does not come near the joint (*see* Fig. 45), which shows the weak part of such joint at C D. You will observe that the centre of the joint A B could not be brought nearer to the cap of the union or it would interfere with its being screwed back,

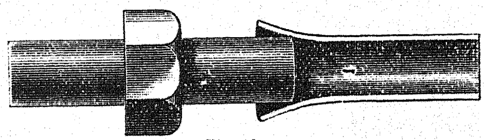


Fig. 46.

therefore only the thinnest part of the metal E F supports the union. With the copper-bit joint fitted as shown at Fig. 46, greater strength is undoubtedly given and plenty of room for unscrewing. Were the brass fittings made longer, wiped soldered joints would be best; I would therefore say as regards joint making, use judgment and discretion in selecting the particular kind of joint to be used. If the work is unimportant or temporary, there is no need to waste time and metal upon it. On the other hand, where you are doing work that is of essential importance to the health of human beings, and work that will be required to last for years and may be centuries, and also when expense is no object, put in the best work you are capable of.

PIPE BENDING.

To bend a piece of lead pipe might appear to the uninitiated a comparatively easy job, but it is really anything but that, especially when we get pipe of largish size: of course very small pipes present little difficulty to bend into almost any shape required; but with each succeeding addition in size the difficulty also increases, especially if the pipes are thin, as in the case of soil pipes. It is very essential that every plumber should be well up in this branch of the trade, for although bends of almost every description can be bought, yet as a rule much bending work has to be done, both in the workshop and on the job. There are several methods of making bends and elbows, but before describing them let us first look a little into the matter, and see what we can learn by a little study of the theory of bending. Look at Fig. 47, which represents a piece of 4-inch pipe bent to a right

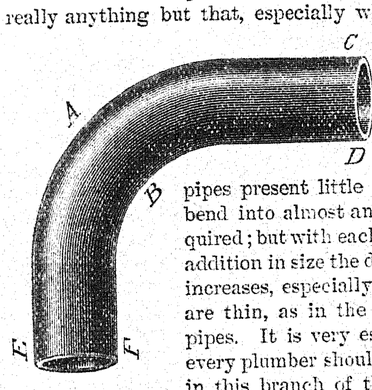


Fig. 47.

angle with a fairly easy sweep, and let A and B represent the inside and outside of the bend. Now it will be evident to the dullest understanding that when the bend was not a bend, that is, when it was a straight piece of pipe, the sides A and B were both of equal length. Now set this bend out on a piece of board and measure round the back of the bend E A C, and then measure the inside of it F B D. You will perhaps, if a novice, be surprised to find that the inside is 6 inches or more shorter than the outside. It is evident then that a considerable amount has gone somewhere, for it will be found that the distance round the outside will be but a trifling degree more than the length of the straight pipe out of which the bend was formed. For some explanation let us look at Figs. 48 and 49. Fig. 48 represents two pieces of pipe placed at right angles to each other, the dotted line shows what a large piece is wanting to fill it up to make a complete elbow or bend.

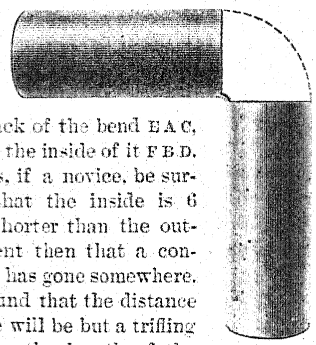


Fig. 48.

Fig. 49 is exactly the reverse of this, it shows a straight piece of pipe with a piece cut out of the middle to allow of the two points A A to be brought together to form an angle similar to Fig. 48. Fig. 50 is the exact shape of the piece cut out, and it would also be found to be just the piece required to fill up the gap in Fig. 48. From these remarks we therefore can deduce the following, first that in making a bend there is an amount of superfluous metal at the throat of the bend and a scarcity at the back; second, that unless this scarcity of metal at the back is, as it were, assisted by the superfluity in the throat, the bend is thinner at the back than at the throat, consequently weaker. How this is to be done I will endeavour to explain. It is a fact that the molecules of which lead is composed can be, by skilful manipulation with the proper tools, directed and made to flow in any direction the plumber wishes.

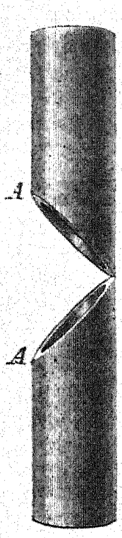


Fig. 49.

Tools used in Bending.—The tools, which are few and simple, are as follow: lead dressers (Figs. 51, 52, 53); bossing stick (Fig. 54), which is a boxwood stick somewhat similar to a dresser, except that the part with which the lead is struck is round instead of flat; hand dummies (Fig. 55); long dummies (Fig. 56); bobbins and followers (Fig. 57). Dressers are made of boxwood and also of hornbeam, two or three sizes are generally required to suit various kinds of work. The dummies are bulbs of solder of the shape shown in the sketches, into which

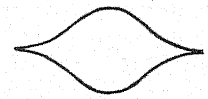


Fig. 50.

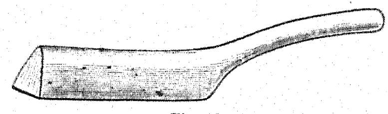


Fig. 51.

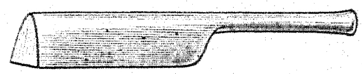


Fig. 52.

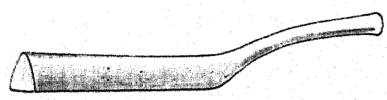


Fig. 53.

Fig. 54.

handles are fitted; the short ones usually have cane or wood handles, and the long ones iron handles. Some plumbers use solid iron rod for them, but $\frac{3}{8}$ or $\frac{1}{4}$ gas tube is much better, as you can get the same sized handle with about half the weight and much more rigidity.

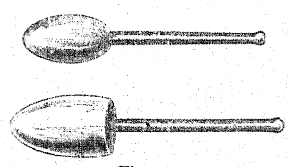


Fig. 55.

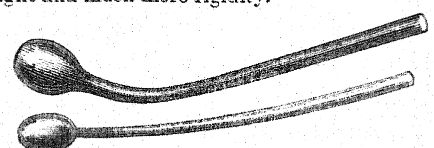


Fig. 56.

Method of bending Large Pipes.—In bending these proceed as follows: take the piece of pipe and mark where the bend is to be, have at hand a bag full of some soft material, hay, straw, or shavings, as a pillow to rest the pipe upon, also a piece of thick carpet, technically called a "felt," to handle the pipe with. The pipe must next be heated. This can be done in various ways: first, by putting lighted shavings into the pipe; second, by using a blow

lamp or gas jet; third, by pouring molten metal upon it. The first way I do not care much about, as if too much should happen to be put in, or any awkwardness displayed in pulling them out when the pipe was sufficiently hot, the pipe would be likely to melt. Moreover the heat is spread over a larger portion of the pipe than is necessary, rendering the pipe awkward to handle. I therefore advise the use of a

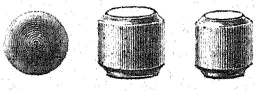


Fig. 57.

blow-lamp or the hot metal in preference to shavings. The pipe should be made quite hot, not merely warm, then place it on the pillows (if a seamed pipe, with the seam at the side), and with the "felt" in your hands grasp round the pipe where the bend is to be; your mate will now pull up the pipe a little, you shaping it as well as possible with your hands as he does so. Should the bend be in the middle of a longish piece of pipe, it will be no trouble to pull up; but if the bend is near the end of the pipe, a mandrel of wood must be inserted to assist; this should just fit the pipe and enter 6 or 7 inches or even more if it will allow of it. Having pulled up a little way, you will find that the pipe has gone in somewhat at the throat and expanded at the sides. Next turn the pipe on one side and take the dresser and give two or three sharp raps on the bulged part, striking from the throat towards the back so as to drive the molecules of lead where they are most required, viz., at the back of the bend; turn over and repeat the operation on the other side. Next take the dummy, long or short as required, and gently dummy out the throat; do not strike violently, and mark the position and result of every blow; be careful not to strike the back of the bend. Now repeat the warming operation, and again pull up the pipe a little. Then let the labourer take the dummy and knock up the bulged part as before, whilst with the dresser and bossing stick you work the sides in, always directing the blows in a sort of driving way to the back, in order to thicken the lead at that part. Continue these operations till the bend is of the required shape. It is possible for a skilful plumber to so work this that every part of the bend shall be of equal thickness; though certainly there are a great many who do not reach such a degree of excellence, still that is the point to aim at, and the art of bending cannot be said to be attained till that can be done.

Bobbins and Followers.—Fig. 58 shows a piece of pipe with the interior partly shown to exhibit the method of using these appliances. After the warming and pulling up of the pipe just described, instead of using the dummies and dressers, and sometimes in conjunction with them, a round ball of wood slightly smaller than the bore of the pipe,

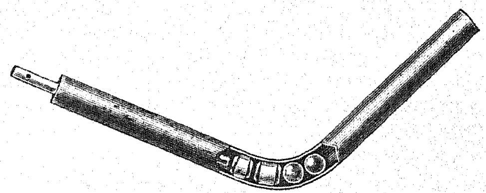


Fig. 58.

termed a bobbin, is driven through, cylindrical blocks of wood (followers) being placed behind it to receive the blows from the driving stick. It is not a very good way of proceeding, as not only does it thin the pipe at the heel of the bend, but the followers are apt to bulge out the pipe in passing the bend. In order to minimise this danger, care should be taken that the edges of the followers are well rounded off, and if both they and the bobbin are greased, it will facilitate their passage through the pipe.

Bending Small Pipes.—The bending of small lead pipe, that is, pipe from $\frac{1}{2}$-inch to $1\frac{1}{4}$-inch bore, presents no great difficulty if strong and the bends are not too sharp. Sharp bends should be avoided as much as possible, as they tend to retard the flow of liquid through them. In many cases the plumber can please himself on this matter, and it is his own fault if he make a square bend when an obtuse one would have served the purpose.

Other Methods of bending Lead Pipes.—Lead pipe can also be bent by filling with sand or with water; if bending with water, the water should be poured in hot, the ends tightly plugged, or, better still, hammered together, and a little solder drawn across; it can then with care and a little dressing be bent into either a single bend or an S-shape. If bending with sand, ram it in tightly and warm in the parts where the bend is to come. Neither of these methods is much practised by plumbers.

Patent Pipe-bending Device (Fig. 59).—This tool, recently invented, consists of a strong spiral coil of

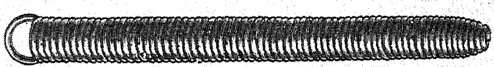


Fig. 59.

wire made of crucible steel slightly tapering from end to end with a loop at one end. The mode of using is to insert the tool into the piece of pipe requiring to be bent, previously greasing or oiling the tool to facilitate its withdrawal. The pipe can then be bent into any shape required. To withdraw

the spiral, turn toward the right and pull at the loop—this slightly diminishes the diameter of the coil and enables it to be withdrawn. The bends have also to be slightly bent back to assist it. It is a tool that is handy for many purposes, but it is not of much use out of the shop, and though 10,000 of them were said to have been sold in a few weeks in this country alone, I do not think that plumbers were in the majority of purchasers, unless it were the ironmonger plumbers that we have heard so much of lately *re* Plumbers Registration Bill. Neither do I think it will ever rank as a recognised plumber's tool.

Bending Wrought Iron Pipe.—In fitting up hot and cold water services in iron pipe, which is much more frequently used for this work than lead pipe, the plumber has often to make bends in his pipes to pass projections, etc. To do this, the pipes must be made red-hot. The method of bending is as follows: heat the pipe to a bright red about 6 inches in length in the place where the bend is to be, take a ladle and cool each side of the red-hot piece with water, rub off the scale with a file, and then take one end and your mate the other and place it between the jaws of a vice, tightening up till it just touches the pipe. Both then press upwards together till the bend is of the required degree of angle: should the pipe slip up as you press, replace it and tighten a little more. Do not lose any more time than you can help between taking out of the fire and bending, or the pipe will get cold and crack in bending; always carefully examine the bend for flaws and test with water before putting in place, as sometimes the pipe cracks at the seam or weld, and is a source of great trouble and annoyance if put in in that condition. Should the pipe crack in bending, do not try to cobble it up in any way, but throw it aside, take another piece of pipe, and try again. When the bend is too near one end to take hold of and pull up, a piece of pipe can be used either inside or outside as a lever. Small pipes will only require one heat to bend them, but the larger sizes such as 1, 1¼, 1½ inch and 2 inches will require two or three heats, bending a little each time. When a bend has to be made to fit in any special place, a template of stout wire should be taken, especially when a journey to the shop from a job has to be made; this will save a lot of unnecessary running to and fro. A little time and care is well expended in making this template. Some workmen pride themselves on what they term a "correct eye," but I have very frequently seen such people have to make two or three journeys to alter their work, to their own confusion and their employer's loss of valuable time.

STEEL AND IRON.—IV.

By William Henry Greenwood,

F.C.S., M.Inst.C.E., M.I.M.E., Assoc. Royal School of Mines.

[*Continued from p.* 141.]

ORES OF IRON (*continued*).

Cleveland Ironstone is a less pure variety of the argillaceous ferrous carbonate, which takes its name from the district of Cleveland, in the North Riding of Yorkshire, where it occurs in a bed of 8 or 10 feet in thickness. This ore will yield about 38 per cent. of ferrous oxide, while the Blackband Ironstone of Scotland will afford 40 per cent., and Staffordshire clay ironstone about 45 per cent. of ferrous oxide. Like the other varieties of ferrous carbonate, it varies in colour according to the degree of the decomposition of the ferrous carbonate, and the proportion of other impurities: thus its colour ranges between dull bluish-yellow and dark blue, and in some specimens becomes almost black; but the darker varieties often contain sensible proportions of ferrous silicate. The pig-iron produced from this ironstone contains from ·25 to 1·5 per cent. of phosphorus, and hence it could not be used for the manufacture of steel until the invention of the Thomas-Gilchrist or basic process for the manufacture of Bessemer steel; but by the basic process the phosphorus can be eliminated from the pig-iron during the Bessemer conversion, and Cleveland ironstone has thus become available for the manufacture of a pig-iron suitable for conversion into Bessemer steel. In practice from 65 to 68 cwt. of Cleveland ironstone as received from the mines is required to produce a ton of pig-iron.

Blackband Ironstone is a clay ironstone, containing from 15 to 25 per cent. of bituminous, coaly, or other carbonaceous matter, which gives to it almost the appearance of coal; it occurs in beds most largely in Lanarkshire and Linlithgowshire, to a much smaller extent in North Staffordshire, and also in South Wales. Owing to the large amount of carbonaceous matter contained in this ore, it can be calcined in heaps without the addition of any further fuel. The raw ore will average about 40 per cent. of ferrous oxide, 26 per cent. of carbon dioxide, 10 per cent. of clay, and 17 per cent. of organic matter.

The principal Iron-Mining Districts of Great Britain are Lincolnshire, Northamptonshire, Staffordshire, Somersetshire, Gloucestershire, Cumberland, Lancashire, Yorkshire, and the valleys of the Clyde and Forth in Scotland. Of these, Lincolnshire raises a soft and loose calcareous brown hæmatite from a bed of 10 ft. to 18 ft. in thickness occurring in the Lower Lias limestone. The average percentage of iron in the ore is only about 22·5 per

cent., and the ore is used largely for mixing with clay ironstones such as those of Cleveland. The Northamptonshire stone is also a brown hæmatite, but it is siliceous and not calcareous in its character; hence for only the pig-iron smelted from haematite iron ores could then be used for conversion into steel by those processes. Previous to that time the ores had only been raised for mixing with the less

ANALYSES OF IRON ORES.

	Magnetic Iron Ore.	Red Hæmatite.	Brown Hæmatite.	Spathic Iron Ore.	Clay Ironstone.	Cleveland Ironstone.	Blackband Ironstone.
	Dannemora Ore.	Barrow-in-Furness.	Northamptonshire.	Somersetshire.	South Staffordshire.	Eston.	Scotland.
Ferric Oxide, Fe_2O_3 . . .	27·55	94·88	56·20	0·81	0·40	3·60	2·72
Ferrous Oxide, FeO . .	58·93	...	Trace	43·84	45·86	39·92	40·77
Manganous Oxide, MnO . .	0·10	0·04	0·20	12·64	0·96	0·95	...
Alumina, Al_2O_3 . . .	0·29	0·07	2·43	0·01	5·86	7·86	Clay 10·10
Lime, CaO	0·38	0·34	0·49	0·28	1·37	7·44	0·90
Magnesia, MgO . . .	0·61	Trace	0·17	3·63	1·85	3·82	0·72
Silica, SiO_2	12·54	4·55	29·09	0·07	10·68	8·76	..
Carbon Dioxide, CO_2 . .	0·12	...	...	38·86	31·02	22·85	26·41
Phosphoric Anhydride P_2O_5 .	Trace	0·03	0·84	...	0·21	1·86	...
Sulphur	0·04	...	...	...	Trace	0·11	...
Iron Pyrites, FeS_2 . . .	...	0·47	...	...	0·10	...	...
Water	0·11	...	10·90	0·18	1·77	2·97	1·06
Organic Matter . . .	...	...	...	...	2·40	Potash 0·27	17·38
Percentage of Iron . . .	62·60	66·42	39·34	34·67	29·12	33·62	33·57

the ore is known sometimes as Northamptonshire sand, and owing to its siliceous character is often mixed with Lincolnshire ores at the furnaces of that county. It is also smelted on the spot, besides being sent to Staffordshire, Derbyshire, and South Wales for mixing purposes. In Staffordshire are blackbands of 1 ft. to 4 ft. in thickness, as also clay ironstone in a bed of about $3\frac{1}{2}$ ft. in thickness; this mineral field is not large, yet it affords a larger output of coal measure ironstone than any other county. In Somersetshire the ore near the surface is brown hæmatite, but in the Brendon Hills are irregular lodes of a spathic ore containing 13 or 14 per cent. of manganous oxide, and this ore has been largely smelted for a spiegeleisen containing as much as 20 per cent. of manganese. Gloucestershire and the Forest of Dean yield a brown hæmatite, which for the most part is very soft and easily worked; it differs, however, widely in composition, and occurs in large *pockets* or churns in the uppermost beds of the Carboniferous Limestones. In Cumberland and Lancashire are red and brown hæmatites, filling fissures and lake-like basins either in the inclined carboniferous limestones of these counties, or more rarely in Silurian rocks. The comparative freedom of these ores from sulphur and phosphorus led to a vastly increased demand for them, and a consequent development of the mining industries of these counties when the acid Bessemer and Siemens open hearth methods of producing steel were introduced in 1857–60, pure and poorer ironstones of Staffordshire, etc. The North Riding of Yorkshire is notable for the extensive bed of clay ironstone of from 8 ft. to 10 ft. in thickness which occurs in the Cleveland Hills, and which is largely transported to, and smelted in, the blast-furnaces of the Middlesbrough district. From the Scotch mines there was formerly raised large quantities of the celebrated blackband ironstone, but this ore has been largely worked out, and the furnaces of the district are now supplied principally with clay ironstones and some imported ores from Spain.

PREPARATION OF IRON ORES; CALCINATION AND WEATHERING.

The ores from which iron is obtained are not generally subjected to any expensive or complicated mechanical treatment like that to which the ores of metals like copper, tin, lead, etc., are submitted. Exceptions there are, however, in the case of Pea iron ore (an argillaceous brown ironstone whose particles are cemented together by a clay containing but little iron), in which case the clay is separated by agitation in sheet-iron perforated cylinders, through which a current of water flows, thereby carrying away the lighter clay, whilst the heavier iron ore remains behind. Another exception is afforded by the titaniferous ironsands of Canada, which are often concentrated by washing them in a gentle current of water on shaking tables of about 20 ft. in length, when the

lighter siliceous particles are removed from the heavier ironsand. These exceptions do not form, however, any appreciable proportion of the workable ores of iron.

The only preliminary mechanical treatment to which iron ores are subjected in England, prior to roasting or calcination, is to break them up into fragments of a fairly uniform size, the size depending upon that of the furnace and the ease with which the ore is reduced. Thus, the ore and fluxes for use in the large furnaces of the Cleveland district are broken into pieces approximately of from 4 in. to 6 in. cubes; for the hæmatite furnaces the materials are charged direct without breaking, or are broken into cubes of two inches resembling road-metalling, whilst for the still smaller furnaces employed in Sweden the pieces are only about one-inch cubes.

The calcination or roasting of iron ores has for its object the expulsion of water, carbon dioxide (CO_2), sulphur, and the volatile or other matters, which, under the influence of heat, or the combined action of heat and atmospheric air, are capable of volatilisation; the process also converts *ferrous oxide* or *ferrous carbonate* into *ferric oxide*, thereby preventing the loss of iron which otherwise occurs when silica and ferrous oxide are brought into contact in the furnace, owing to the production of slags of ferrous silicate, which are difficult of subsequent reduction; and lastly, calcination renders the ores more or less porous, and so more easily permeated by the reducing gases of the blast-furnace.

Ferrous silicates, by roasting in an oxidising atmosphere, also become converted largely into ferric and magnetic oxide of iron; hence, when forge or mill cinder, which is essentially a ferrous silicate containing from 40 to 60 per cent. of iron, is to be added to the blast-furnace (as is done in the manufacture of the inferior pig known as cinder-pig), the cinder is first roasted to convert it as far as possible into ferric and magnetic oxides, which are much more easily reducible in the blast-furnace than the original silicates. Calcareous or compact ores rich in iron, which have but little tendency to clot or to become matted, may be subjected to a more prolonged and higher temperature of calcination than can be adopted with ores containing free silica, readily fusible silicates, or manganiferous compounds in notable proportions. The loss of weight during roasting or calcination amounts to 25 or 30 per cent. with Welsh argillaceous ores; to 50 per cent. in blackbands; to 6 per cent. with red hæmatites; and to about 12 per cent. with brown hæmatites. It is not the practice in the hæmatite districts of England to subject the ores to any preliminary calcination, since water is the chief volatile ingredient, and that is expelled by the heat of the ascending gases of the blast furnace as the ore lies in the upper zones of the furnace.

In the Middlesbrough districts the clay ironstone is usually calcined before smelting, but with the great increase in height of the blast furnaces of that locality, preliminary calcination becomes less important, since the heat of the escaping furnace gases is sufficient to expel water and carbon dioxide from the whole of the ironstone during the time that the stone lies in the upper zones, and before it reaches the hotter zones of the furnace. But calcination in kilns effects a more perfect separation of sulphur than is possible in the blast furnace.

ANALYSES OF THE RAW AND CALCINED CLEVELAND STONE.

	Cleveland Ore or Stone, uncalcined.	Cleveland Stone, after calcination.
Ferric Oxide, Fe_2O_3	2·60	66·25
Ferrous Oxide, FeO	38·06	...
Manganous Oxide, MnO	0·74	...
Manganic Oxide, Mn_3O_4	...	0·65
Alumina, Al_2O_3	5·92	7·72
Lime, CaO	7·77	6·46
Magnesia, MgO	4·16	4·78
Potash, K_2O	Trace	0·02
Carbon dioxide, CO_2	22·00	...
Water, OH_2	4·45	..
Silica, SiO_2	10·36	11·87
Sulphur, S	0·14	...
Phosphoric Anhydride, P_2O_5	1·07	1·13
Sulphuric Anhydride, SO_3	...	0·90

Roasting or calcination of iron ores is effected in *clamps* or *open heaps, between closed walls*, or in variously designed *kilns*, but in all of these it is necessary to carefully regulate the temperature, so that the ores may not during the process be softened, partially fused, or clotted together into compact masses impervious to the ascending gases in the subsequent smelting operation. With such ores as the Blackbands, containing much carbonaceous matters, care should also be exercised that the temperature does not rise sufficiently high to effect a partial reduction of the metal in the ore.

Roasting or calcination in open heaps, as carried on in South Wales, Staffordshire, etc., consists in placing upon a piece of level ground a layer or bed of coal several inches in thickness, upon which is put ore and fuel in alternate layers, until the pile so formed reaches to a height of from four to five feet. The proportion of ore to fuel in the several layers is made to increase from the bottom towards the top of the pile. The fire is first lighted at the base of the pile just as in charcoal burning; and, as the process advances, if any portion of the

surface indicates that the combustion is proceeding too rapidly, or that the calcination is too active in any part, then such part or parts are damped down with small ore, so that the process in those directions may be checked. The process of calcination thus continues until the whole of the coal in the pile has been consumed.

Blackband ores frequently contain from 25 to 30 per cent. of combustible matters, and these or such other ores as contain much bituminous matter are usually roasted without any further addition of fuel or carbonaceous material.

The general conduct of the process of calcining in heaps is the same in all countries and localities, yet considerable variations are made in the practical details and in the size of the piles, according to the nature and quality of the ores. Thus ores containing much carbonaceous matter, sulphur, or other combustible substance, are treated in longer heaps, with less width at the base, than those above described, whilst the height of the pile rarely exceeds about 3 feet; such heaps are preferable for the roasting of these classes of ores, since they do not attain to so high a temperature as the larger heaps, and the ore is not, therefore, so liable to become fused together. Further, the bituminous class of ores requires to be calcined in larger pieces than is the case with argillaceous and other ores free from combustible matters; but ores, such as those of Westphalia, which are less rich in carbonaceous matters, are usually treated in large heaps of from 20 to 30 feet in width, and from 15 to 20 feet in height.

Roasting in heaps, although still pursued in some localities, is not the best method, since it involves in South Wales and Staffordshire the consumption of about $2\frac{1}{2}$ cwt. of coal per ton of ore; besides which there is greater difficulty than with kilns in regulating the temperature throughout the pile, so as to prevent the central portions becoming clotted together or even fused, whilst other portions are still unroasted when treating spathic, pyritous, or carbonaceous ores.

Calcination between closed walls is pursued in the Midlands, and in the Hartz. In the latter clay ironstone is treated with charcoal dust or breeze as the fuel, and the walls of the pile are from 6 to 12 feet in height built around three sides of a rectangular area, the floor of which is usually made to slope slightly towards the front or open side. In the enclosing walls are constructed draught-holes, of about four inches in diameter, which are in communication with chimneys built up of the larger pieces of ore, in the interior of the pile, and a circulation of air is thus effected through the draught- or vent-holes and the chimneys. The temperature and draughts are more under control, and there is a less expenditure of fuel, with more perfect calcination of the ore, than occurs in open heaps.

Roasting or calcination in kilns is more economical in both fuel and labour, the temperature is also more under control, and the calcination of the ore is more uniform than when the process is performed in open heaps. In South Wales, the *kilns* are of rough massive stonework, with parallel sides and semicircular ends. Kilns which measure 20 feet in length, 18 feet in height, tapering from 2 feet in width at the bottom to 9 feet across at the top, hold about 70 tons of material, fuel and ore together. The masonry of such kilns is lined with fire-brick, and the bottom of the kiln is formed of cast-iron plates. Arches built in the masonry allow of openings being made at the level of the floor for the extraction of the calcined or roasted ore from the bottom of the kiln, while the calcination is still going on in the upper zones of the kiln; other openings above these serve for the admission of the air required for combustion and maintenance of the heat required for the calcination.

These kilns are charged by first making three fires upon the cast-iron bottom, and then placing the ore around these fires to the depth of a few inches, following which, when this has attained to a red heat, is placed another layer of some nine inches in thickness of ore and small coal, in the proportion of about 1 cwt. of coal to 1 ton of ore; this last layer, after attaining to redness, is, in its turn, again covered with a like stratum of a mixture of coal and ore, and so on until the kiln is quite filled to the top, by which time the ore first introduced is ready for withdrawal, an operation effected through the openings at the floor level already mentioned. Fresh additions of ore and fuel are then continually added at the top of the kiln to replace that which is withdrawn from the bottom, and in this manner the calcination proceeds uninterruptedly in the upper zones of the kiln, whilst the roasted ore is at the same time being withdrawn from the bottom. The descent of the charge from top to bottom of the kiln occupies from three to four days.

COTTON SPINNING.—IV.

By Henry Riddell, M.E.

[*Continued from p.* 145.]

COTTON BUYING AND STORING.

Cotton Buying.—The position of buyer is one of the most responsible which any branch of the cotton spinning trade offers, and should be filled by a man of thorough practical knowledge of the processes employed, and of the effect upon the working of different variations in the quality of the

fibre. At the same time it requires a man to be perfectly in touch with the market, to feel its fluctuations, and to make certain that he buys, as far as necessity will allow, at the best time and in the best quarter. As there is no satisfactory standard of purity or condition, a cotton buyer requires to have developed by constant observation the faculty of deciding what amount of foreign matter is present, and to what extent it affects the value for the particular yarn spun.

He will often find it possible to buy, at a farthing a pound less, a cotton which for his particular purpose will serve as well as that usually employed. In fact the difference between two buyers may very well mean that between a good dividend and none, so that no manager or owner should be satisfied without rendering himself, by careful study and observation, master of this important branch of the trade. Where the manager possesses the proper qualifications, there is much to be said in favour of combining his office with that of buyer, as it is only natural that the man responsible for the quantity and quality of the production should be the person most anxious to provide the most suitable raw material at the lowest possible price.

As bearing upon the question of cotton buying, it is advisable to devote a little space to the examination of the different impurities found in the cotton as it reaches this country. The natural impurities have been previously mentioned, as seed or leaf particles and unripe fibre, as well as that proportion of dust which is almost unavoidable in some climates. There are, however, added impurities, added sometimes by accident, but more often by intention. Among those occurring by accident may be mentioned bolts, pieces of steel ties, and even in some cases cigars and boxes of matches. The most frequent additions with fraudulent intent are sand and water, both of which substances are present naturally as well in most samples of cotton.

Cotton is very hygroscopic, its weight varying from day to day according to the dampness of the air, but in many cases the addition of water is plainly apparent; as to sand it is sometimes in such quantity as to make it impossible to believe its presence to be accidental.

The varying of cotton in weight according to weather may reach four per cent., but in many samples moisture amounts to ten or twelve, or even in some instances to twenty per cent. of the weight, so that a buyer needs to be sharply on guard against this species of adulteration.

The cotton being purchased requires in most cases to be stored until needed, and where this storage is at the mill, it is a matter of course that the stores should be unconnected with the manufacturing buildings, except perhaps the opening and mixing rooms, which are also better to be in a building not directly connected with the mill proper.

Until the bales are received into the mill, all the manufacturing operations have been performed in the country of growth, and at this point it will be advisable to state the nature and order of the processes still to be employed before the finished product can be placed upon the market.

These are in order of operation—

Bale Breaking and Mixing.—The operation of bale breaking is described by its name, while mixing is required for the purpose of ensuring a yarn of a fixed quality at a price as low as possible.

Opening.—To bring the compressed and matted fibres into a natural condition, and to free the cotton from the grosser impurities.

Scutching and Lapping.—This process continues the opening, and forms a lap or continuous web of cotton fibre to facilitate the further work.

Carding.—This is intended to lay the fibres approximately parallel, and to form a sliver, or loose untwisted rope of cotton.

Drawing.—In this process several slivers are combined into one, and drawn out to a much greater length, which helps to equalise the weight per unit of length, and to further the arrangement of parallel fibres aimed at.

Comb Lapping is a repetition of the doubling as in the drawing frame, and the formation of a roll of sliver for the use of the machinery in the next process.

Combing completes the parallelism of the fibres, and removes any which are too short, or too entangled to be laid parallel. This and the previous process are only employed when spinning the finer and higher qualities of yarn, and are not required for yarns of moderate numbers. After combing the drawing operation may be repeated.

Slubbing signifies the operation of reducing the thickness of the drawn sliver, twisting it very loosely, and building it upon a bobbin.

Roving carries the preceding process further, and may require several repetitions before the spinning.

Spinning.—In this process the manufacture of the yarn is completed by the continued reduction of the rove in size, and the addition of the necessary twist. All further operations are for the convenience of packing, transport, and sale.

MIXING AND OPENING.

Bale Breaking and Mixing.—The actual work of an English cotton mill begins with the "bale breaking" and mixing operations, which were

formerly performed altogether by hand, but are now in great part executed by machinery. In earlier times the mixing and breaking of the bales were carried out as follows:—

The bale ties being cut—an operation for which a powerful pair of shears should always be used in preference to any axe or chisel—the cotton was pulled out in small pieces and spread in a layer a few inches thick upon the floor. This layer being finished, a second was formed upon it, using the other ingredient of the mix and proportioning the layers, which were repeated alternately, in the ratio of the quantity of each class of cotton to be used. The size of the pile varied, but it is always advisable to make a mixing as large as possible, as leading to that uniformity in the quality of the yarn spun which is a great object of every spinner to secure. Nothing irritates buyers more, and more surely injures sales, than uncertainty as to the quality of the yarn turned out, and every manager lays his plans to obtain by all means in his power a reputation for constant uniformity in his spinning. Of course, this can only be approximately accomplished; yet it is wonderful how much may be effected towards the desired result by skill and care in buying and mixing the raw material. Therefore, as has been said, as large a pile as possible was made, and when ready and required for use was drawn down in vertical section by a rake for the supply of the openers.

Except that the bale breaking is now the work of a machine, and that travelling lattices are often used to carry the cotton from the bale breaker to the mixing floor, the above description will apply to present practice.

The need for mixing arises from more than one cause, the leading factors being the desire for economy and the necessity for uniformity. It will easily be understood that no two deliveries of cotton are exactly alike, or would produce yarns identical in appearance and strength if treated in precisely the same way. It is plain, too, that by adding a proportion of cotton of another class the resulting yarn will be altered, and the highest skill of the cotton worker is required to vary those proportions in each mixture so as to arrive as nearly as possible at the same result each time. As to the other reason mentioned, that of economy, it is often the case that if the cheaper cotton were used the yarn would be too low in quality, while if the higher-priced variety were alone employed the resulting yarn would be too expensive for the buyer. It is, however, possible, by combining the two classes in proper proportions, to produce a yarn at a moderate price, and of a quality sufficiently good for the purpose required.

It is not possible to mix cotton properly without careful consideration: the fibres should be approximately of the same class, the colour requires attention, and most essentially the staple, or average length of the fibres, should be the same in cottons intended to be worked together. In cotton where the fibres are naturally very uneven in length, the action of the preparing machinery tends to separate the shortest and throw them out as waste, as in the carding and combing, or in the drawing, to cause irregular thicknesses in the sliver, as will be explained later. It is therefore very important to consider the length of the staple when settling the mixture.

Considering all the difficulties in the way of complete success, it will be agreed that the manager who has paid careful attention to this point, and has really utilised his experience, is much more likely to acquire a reputation for well spun yarns than he who mixes more by guess than by skill. Even with the most experienced man it is advisable to experiment with each mixing, by passing through the different processes a small quantity specially prepared, comparing the yarn with a standard sample kept for the purpose, varying the proportions until satisfied, and then completing the mixing in the light of the experience thus gained. It is impossible to give any standard mixings, as these necessarily vary with the difference in character in successive crops; but the following may give some idea of common usage.

American cotton (Orleans, Texas, etc.) will mix in varying proportions with white Egyptian, Peruvian, or Surats, proper attention being paid to selection. The Peruvian will mix with white Egyptian and American, while the Sea Islands will only mix with cottons of the same class, the length of fibre being so peculiar.

As illustrating the principle, the following short table shows mixings which have been successfully used, but the student is cautioned that each spinner varies the mixing to suit the standard character of his yarn, and therefore the table only illustrates an approximate practice:—

10s to 15s. Say waste and Indian ½ and ½ or 1 to 2.
16s to 20s. Indians alone, or mixed with American, for instance, Dhollerah ⅔, Texas ⅓.
20s to 24s. If so desired can be spun from the better classes of Indian, or Surats ⅗, Texas ⅖.
24s to 28s. Raise the proportion of American to ⅝ or ¾ of the whole.
28s to 36s. Use better qualities of above mix, or substitute Peruvian for Indian.
36s to 40s. Increase the proportion of Peruvian, or use better qualities of American.
40s to 50s. Use say good Middling American, with South American such as Maranhams, or substitute White Egyptian for South American.

50s to 80s. Vary the proportions of South American with the better American, and for the finer numbers use mixtures of White Egyptian and Peruvian, or put in Brown Egyptian with some suitable American.

It is advisable to take careful records of every mix made, keeping a book for the purpose, in which

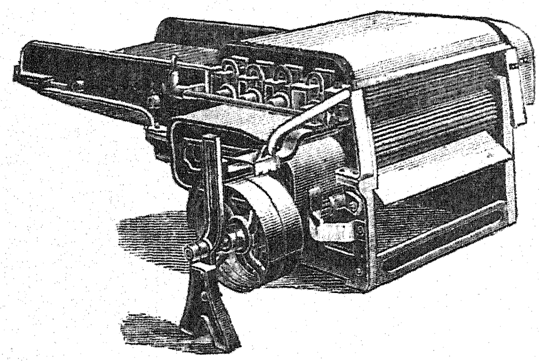


Fig. 9.

should be entered the date, the class of cottons mixed with their actual weights and prices; the total weight requires to be carried out and an average price struck after making proper allowances for waste in the different processes, such allowances to be duly entered in each case. The weight of the bales should be entered at the time of their receipt after buying, and this is the weight to be taken as the basis for calculating the total cost, but the bales should be re-weighed at the time of mixing, and any difference entered, as if the cotton were in damp condition when bought and lost weight by drying in store. The weight at the mixing will be the divisor when finding the cost per pound of the mix from the total cost—it is necessary therefore, as well for this purpose as for ordinary store purposes, to carefully enter every bale into a cotton store book, noting its marks and weight, and keeping a column for the re-weighing.

If for any purpose it were thought necessary to mix two cottons of different staples, quite a different process is required. In this case the cotton is passed through the opener without mixing, and a lap formed. Laps of each variety of cotton, in the proportion required, can then be fed to the intermediate scutcher and a mixed lap formed, which requires most careful treatment in all the subsequent processes to ensure an economical result.

The mixing is often done at the bale breaker, when a more than usually skilled hand is required to feed the machine, selecting his cotton from the open bales around him, and mixing it in the necessary proportions on the lattice of the bale breaker. From this mixing machine the cotton is sometimes conveyed by travelling lattices to a store, and afterwards fed by hand to the apron of the opener, as is also sometimes done where the cotton is mixed after the bale breaking. Very frequently, however, where the material is mixed at this stage, it is conveyed by pneumatic trunks direct to the opener, and by this machine opened up, and freed from the grosser impurities, and formed into a lap.

It is, of course, well to as much as possible avoid handling, as lessening the expense, and this latter method of working is very successful in this respect. The machinery employed is ingenious, and has had a very gradual development.

A machine in very common use (Fig. 9) as made by Messrs. Dobson and Barlow, consists of four pairs of rollers geared together in such a manner that each pair runs faster than the preceding set, and provided with change wheels so that any required amount of "draft" can be given between the successive pairs. The top rollers are weighted by spiral springs, thus allowing them to rise if an extra large and hard lump passes. The first three pairs of rollers are constructed by stringing sections resembling coarsely toothed wheels upon an axle, so that any broken section can be withdrawn and economically replaced; the last pair of rollers are coarsely fluted, and deliver the cotton upon the floor, or on a travelling lattice, which may either deliver at a distance, or feed the opener near by. The action of the rollers will be easily understood, as while passing between the first pair of rollers, and before being quite loosed from their hold, the cotton is seized by the second pair, which are driven faster, and by their additional speed is drawn asunder, loosened, and enlarged in bulk. The feed is by a lattice traveller—a device of very frequent employment in cotton machinery—its construction being very simple does not require a separate diagram. It is made by laying side by side slips of wood, leaving slight intervals between, and connecting them by means of flat chains to form an endless belt, which may be extended to any convenient distance supported by rollers, and put in motion by driving one or more of these rollers, which carry chain wheels acting upon the lattice connections.

An improvement upon the four pairs of rollers consists in using two single rollers only of the toothed type, preceded and followed by pairs of smooth feed and delivery rolls. A series of levers are provided, resembling the pedal levers to be described in connection with the opening

machines, lying quite close together, and bearing along the whole bottom surface of the toothed rollers. These levers yield singly when a lump passes, and allow it to be drawn asunder by the rollers without affecting the adjacent levers, thus aiding in keeping a more regular passage through the machine

PROJECTION.—IV.

[*Continued from p.* 149.]

PROBLEMS ON LINES.

WE have already seen (Fig. 9) that in general the true length of a line is different from the length of its plan or elevation, the following problem is therefore important.

Problem 1.—Given the plan $a\,b$ and the elevation $a'\,b'$ of a line (Fig. 43), to determine its true length.

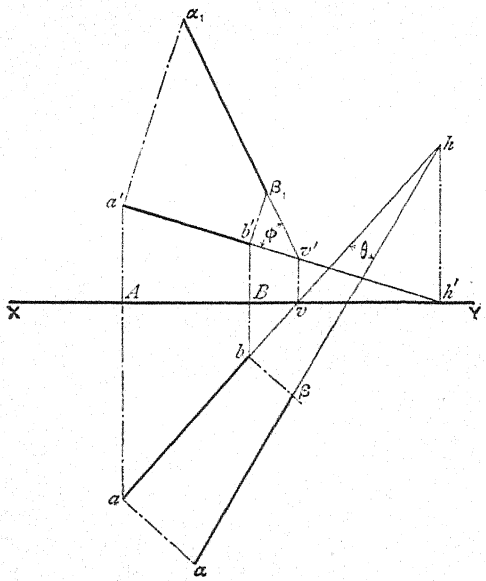


Fig. 43.

Consider the line in space together with its projections. Let A B (Fig. 44) be the line in space, $a\,b$ and $a'\,b'$ its projections on the horizontal and vertical planes respectively. The line A B, its plan $a\,b$, and the projectors A a and B b, form a quadrilateral, with the angles at a and b right angles. Also the projector a A is equal to $A\,a'$, the distance of the elevation a' above X Y; similarly $b\,\text{B} = B\,b'$. Therefore in Fig. 43 draw $a\,\alpha$ and $b\,\beta$ at right angles to the given plan $a\,b$ and equal to $A\,a'$ and $B\,b'$ respectively. $\alpha\,\beta$ is the true length required, since the quadrilateral $a\,b\,\beta\,\alpha$ (Fig. 43) is equal in every respect to the quadrilateral $a\,b$ B A (Fig. 44).

It is easily seen that the true length could also be found by drawing $a'\,\alpha_1$ and $b'\,\beta_1$ at right angles

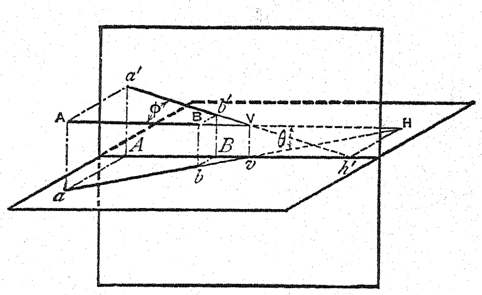


Fig. 44.

to $a'\,b'$ (Fig. 43) and equal to $A\,a$ and $B\,b$ respectively; $\alpha'_1\,\beta_1$ will be the true length since the quadrilaterals $a'\,b'\,\beta_1\,\alpha_1$ (Fig. 43) and $a'\,b'$ B A (Fig. 44) are equal in every respect.

Every straight line, if produced far enough, cuts the horizontal plane and the vertical plane, or is parallel to one or both co-ordinate planes.

Traces.—The point where a straight line cuts the $\genfrac{}{}{0pt}{}{\text{V.P.}}{\text{H.P.}}$ is called the $\genfrac{}{}{0pt}{}{\text{vertical}}{\text{horizontal}}$ trace of the line.

Problem 2.—Given the projections of a line, find its traces.

The $\genfrac{}{}{0pt}{}{\text{plan}}{\text{elevation}}$ of every point in the $\genfrac{}{}{0pt}{}{\text{vertical}}{\text{horizontal}}$ plane is in the X Y, therefore the $\genfrac{}{}{0pt}{}{\text{plan}}{\text{elevation}}$ of the $\genfrac{}{}{0pt}{}{\text{vertical}}{\text{horizontal}}$ trace is the intersection $\genfrac{}{}{0pt}{}{v}{h'}$ of the $\genfrac{}{}{0pt}{}{\text{plan}}{\text{elevation}}$ of the line with X Y (Figs. 43 and 44). The $\genfrac{}{}{0pt}{}{\text{elevation}}{\text{plan}}$ of the $\genfrac{}{}{0pt}{}{\text{vertical}}{\text{horizontal}}$ trace is got by taking a projector from the $\genfrac{}{}{0pt}{}{\text{plan}}{\text{elevation}}$ $\genfrac{}{}{0pt}{}{v}{h'}$ of the $\genfrac{}{}{0pt}{}{\text{vertical}}{\text{horizontal}}$ trace, to meet the given $\genfrac{}{}{0pt}{}{\text{elevation}}{\text{plan}}$ of the straight line.

The inclination of a line to the $\genfrac{}{}{0pt}{}{\text{horizontal}}{\text{vertical}}$ plane is the angle between the line in space and its $\genfrac{}{}{0pt}{}{\text{plan.}}{\text{elevation.}}$ Thus in Fig. 44 the inclination of the line A B to the $\genfrac{}{}{0pt}{}{\text{horizontal}}{\text{vertical}}$ plane is the angle between A B and its $\genfrac{}{}{0pt}{}{\text{plan}}{\text{elevation}}$ $\genfrac{}{}{0pt}{}{a\ b}{a'\,b'}$; *i.e.*, the angle $\genfrac{}{}{0pt}{}{\text{A H}\,a}{\text{A V}\,a'}$, which is usually denoted by the Greek letter $\genfrac{}{}{0pt}{}{\theta\ \text{(theta).}}{\phi\ \text{(phi).}}$

Problem 3.—Given the projections of a line, to

determine its inclinations to the co-ordinate plane.

Comparing Figs. 43 and 44, it is evident that the angle between the two lines $\genfrac{}{}{0pt}{}{a\,b \text{ and } \alpha\,\beta}{a'\,b' \text{ and } \alpha_1\,\beta_1}$ in Fig. 43 is the same as the angle between A B and $\genfrac{}{}{0pt}{}{a\ b}{a'\ b'}$ in Fig. 44. It is also evident that the lines $\genfrac{}{}{0pt}{}{a\ b}{a'\ b'}$ and $\genfrac{}{}{0pt}{}{\alpha\ \beta}{\alpha_1\ \beta_1}$ in Fig. 41 meet in the point $\genfrac{}{}{0pt}{}{h}{v'}$, therefore the angle of inclination of the line A B to the $\genfrac{}{}{0pt}{}{\text{horizontal}}{\text{vertical}}$ plane is the angle $\genfrac{}{}{0pt}{}{a\ h\ \alpha}{a'\ v'\ \alpha_1}$; the construction being the same as in the preceding problems.

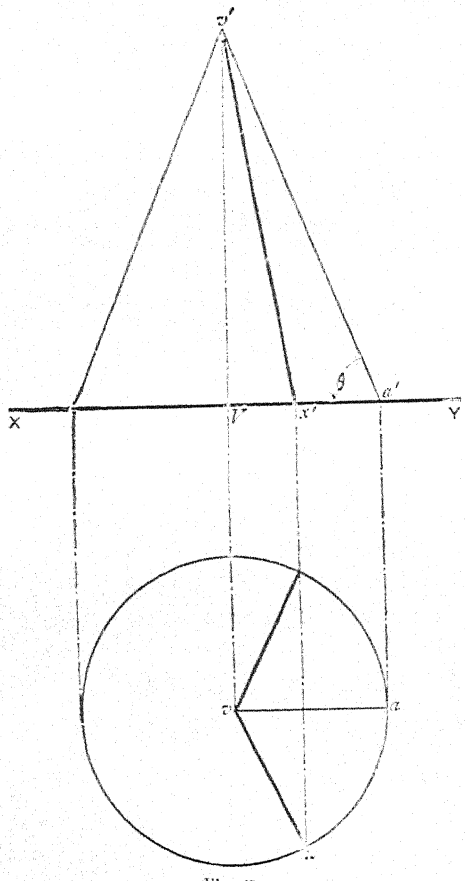


Fig. 45.

Problem 4.—To draw the projections of a line, having given its inclination to one of the co-ordinate planes and the angle which its projection on that plane makes with X Y.

If a right circular cone be placed with its base on the $\genfrac{}{}{0pt}{}{\text{horizontal}}{\text{vertical}}$ plane, all the straight lines lying on the surface of the cone—which all pass through its vertex—will have the same inclination to the $\genfrac{}{}{0pt}{}{\text{horizontal}}{\text{vertical}}$ plane.

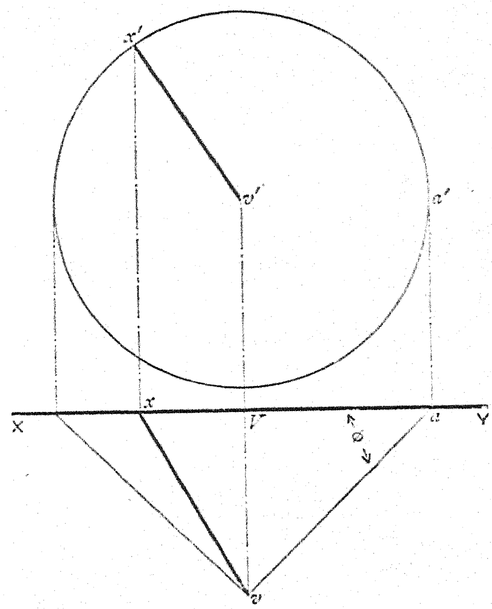


Fig. 46.

Therefore from any point $\genfrac{}{}{0pt}{}{a'}{a}$ in X Y (Fig. $\genfrac{}{}{0pt}{}{45}{46}$) draw $\genfrac{}{}{0pt}{}{a'\ v'}{a\ \ v}$ at an angle with X Y equal to the given inclination $\genfrac{}{}{0pt}{}{\theta}{\phi}$ of the line to the $\genfrac{}{}{0pt}{}{\text{horizontal}}{\text{vertical}}$ plane. The length $\genfrac{}{}{0pt}{}{a'\ v'}{a\ \ v}$ should be equal to the given length of the line. From $\genfrac{}{}{0pt}{}{v'}{v}$ draw a projector and in it take any point $\genfrac{}{}{0pt}{}{v}{v'}$ as the $\genfrac{}{}{0pt}{}{\text{plan}}{\text{elevation}}$ of the vertex of the cone. Let V be the point where this projector cuts X Y, then the radius of the base of cone is $= \genfrac{}{}{0pt}{}{V a'}{V a}$ and with centre $\genfrac{}{}{0pt}{}{v}{v'}$ a circle is described with this radius. Draw a radius $\genfrac{}{}{0pt}{}{v\ x}{v' x_1}$ at an angle with X Y equal to the given angle which the $\genfrac{}{}{0pt}{}{\text{plan}}{\text{elevation}}$ makes with X Y, $\genfrac{}{}{0pt}{}{v\ x}{v'\ x'}$ is the required $\genfrac{}{}{0pt}{}{\text{plan}}{\text{elevation}}$ and a projector from $\genfrac{}{}{0pt}{}{x}{x'}$ to X Y determines $\genfrac{}{}{0pt}{}{x'.}{x\ .}$ $\genfrac{}{}{0pt}{}{v'\ x'}{v\ \ x}$ is the required $\genfrac{}{}{0pt}{}{\text{elevation.}}{\text{plan.}}$

If the distance of the ends of the line from the

co-ordinate planes, as well as its inclination, is given, the student will have to draw the cone with its vertex and base in such a position as will suit the given conditions.

By studying Figs. 26, 45, and 46 it is easily seen that all lines having a given inclination to the $\genfrac{}{}{0pt}{}{\text{horizontal}}{\text{vertical}}$ plane have their $\genfrac{}{}{0pt}{}{\text{plans}}{\text{elevations}}$ of equal

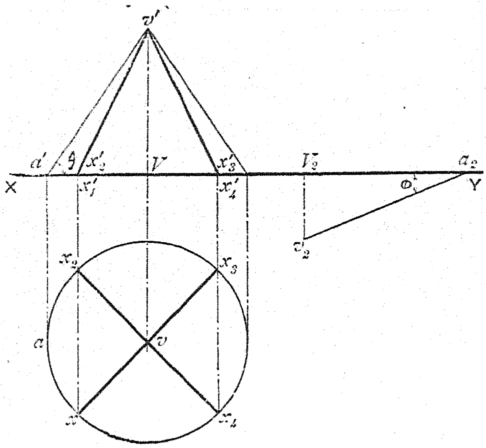


Fig. 47.

length, while the lengths of the $\genfrac{}{}{0pt}{}{\text{elevations}}{\text{plans}}$ may vary within certain limits. In Fig. $\genfrac{}{}{0pt}{}{45}{46}$ the length of the $\genfrac{}{}{0pt}{}{\text{elevation}}{\text{plan}}$ of a line on the cone varies from $\genfrac{}{}{0pt}{}{v'\,V}{v\,V}$ to $\genfrac{}{}{0pt}{}{v'\,a'.}{v\,a.}$ Therefore, given the length of a line and its inclination to the $\genfrac{}{}{0pt}{}{\text{horizontal}}{\text{vertical}}$ plane, we can at once find the length of its $\genfrac{}{}{0pt}{}{\text{plan.}}{\text{elevation.}}$ We will use this principle in solving the following problem.

Problem 5.—Draw plan and elevation of a line, having given its inclinations to the co-ordinate planes.

Draw $a'\,v'$ making with X Y the given angle of inclination to the horizontal plane θ (Fig. 47). Make the length $a'\,v'$ equal to the given length of line. Draw the projector $v'\,V\,v$, with centre v and radius equal to $a'\,V$ draw a circle which will represent the plan of the cone on which all lines passing through V and inclined θ to the H. P. must lie. From any point a_2 in X Y draw $a_2\,v_2$ equal to $a'\,v'$ and inclined ϕ to X Y, ϕ being the given angle of inclination to the V. P. Draw $v_2\,V_2$ perpendicular to X Y. $a_2\,V_2$ is the length of the elevation of all lines of true length $a_2\,V_2$ and inclined at the angle ϕ to the V. P. Therefore with centre v' and radius equal to $a_2\,V_2$ draw a circular arc cutting X Y in x'_1. $v'\,x'$ is the required elevation. A projector from x'_1 to the circle gives x_1 the plan of the extremity of the line. $v\,x$ is the required plan.

Note.—There are four lines lying on the cone having the given angles of inclination to the co-ordinate planes. They are represented on Fig. 47.

Note.—The sum $\theta + \phi$ must not be greater than 90°.

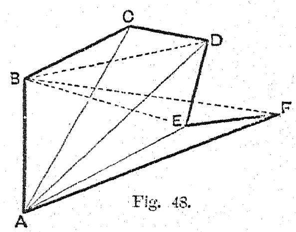


Fig. 48.

Problem 6.—The plan $a\,b\,c$ and elevation $a'\,b'\,c'$ of a triangle are given, to determine its true shape. This problem is solved by finding the true lengths

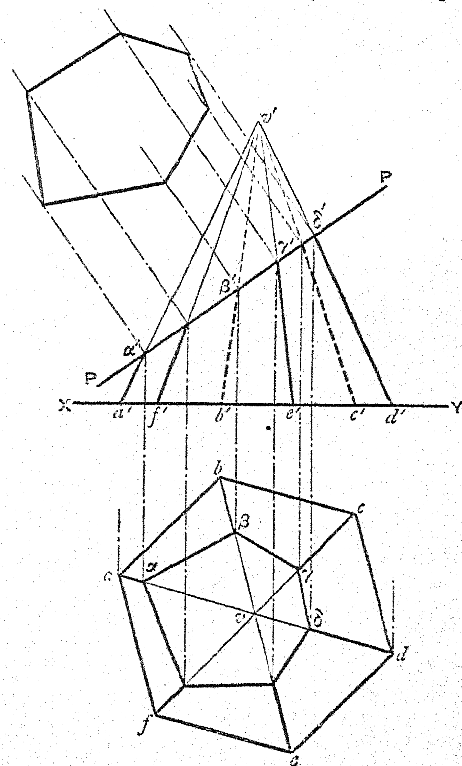


Fig. 49.

of the sides A B, B C, C A by Problem 1, and then constructing a triangle having its three sides equal to A B, B C, C A respectively.

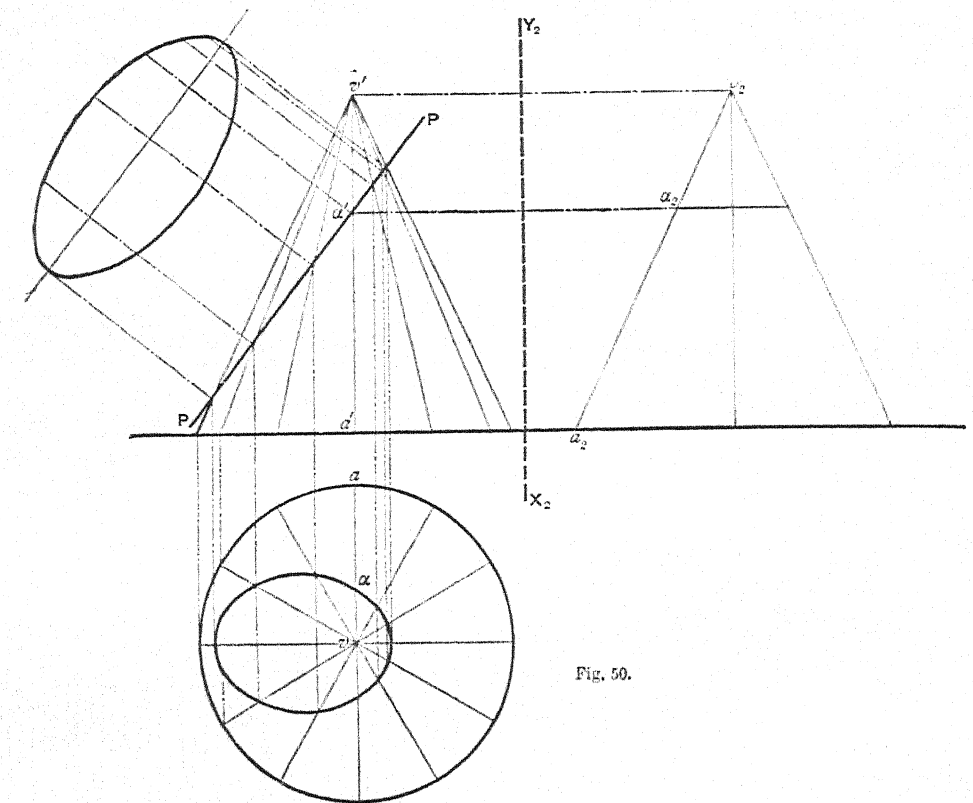


Fig. 50.

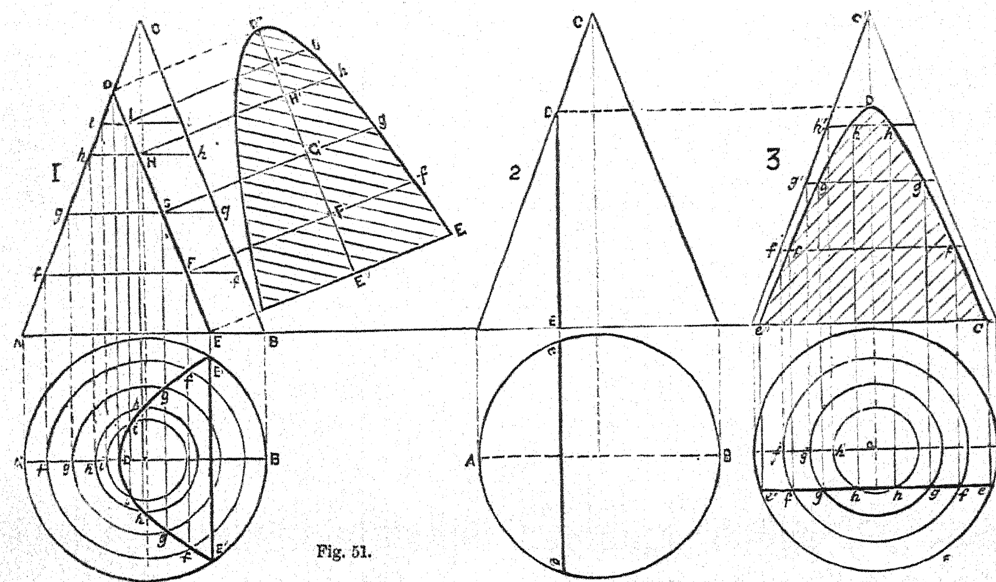


Fig. 51.

In the same way we can find the true shape of any plane polygon A B C D E F A, whose plan and elevation are given. First find the true shape of the triangle A B C, then of the triangle A C D, then A D E, then A E F. By placing these together in the proper way the true shape A B C D E F A will be obtained. The errors due to inaccuracy of drawing will be less if the triangles taken have all the same base, for instance the triangles taken may be A B C, A B D, A B E, A B F (Fig. 48). The plan *a b c d e f* and the elevation *a′ b′ c′ d′e′ f′* cannot be taken arbitrarily in the above problem, or the polygon will not necessarily lie in a plane. The student may assume any polygon *a′ b′ c′ d′ e′ f′* for the elevation of the given polygon, and a straight line for its plan. The plane of the polygon will thus be vertical, but inclined to the vertical plane. A second plan may be found on a new X Y by the method explained on page 146, and the true shape of the polygon may then be determined.

SECTIONS OF SOLIDS BY PLANES.

We have seen that a plan and elevation, if both full enough, are theoretically sufficient to represent any object; but there are many objects which can be best represented practically by showing the shape of a cut made by a plane. For example, a projection of a steam engine cylinder with all its lines not visible from the outside drawn dotted would be rather confusing. The arrangement of the interior of a house cannot be clearly shown on an outside elevation. But if the cylinder or house be supposed to be cut by a plane, and the part between the plane and the observer removed, the projection of the remainder will give a clear idea of the construction.

In this chapter we will consider the section of the simpler solids, by planes at right angles to either the horizontal or vertical plane.

Problem 1.—Given plan and elevation of a polyhedron, find the plan and true shape of the section by a plane at right angles to the V.P. and inclined to the H.P.

As an example, take the hexagonal pyramid in Fig. 23, cut by the plane P P at right angles to the V.P. and inclined to the H.P. (Fig. 49).

The elevation *v′ a′* of the edge V A is cut by the trace of the plane P P in the point α', α' is therefore the elevation of the intersection of the edge V A with the plane P P; from α' draw a projector to meet *v a* in α, α will be the plan of the point of intersection of the edge V A with the plane P P. Similarly the points β, γ, δ, etc., are determined.

Now since the intersection of two planes is a straight line, the plan of the intersection of the face V A B with the plane P P will be the straight line $\alpha\,\beta$. Thus the plan of the section of the solid is $\alpha\,\beta\,\gamma\,\delta$ . . . .

The plan of the lower part of the solid is drawn in thick lines.

The true shape of the section of the solid is got by making a new plan on a new ground line parallel to P P, or coinciding with P P. The new plans of the points of intersection are marked off along the projectors at the same distance from the new X Y as the old plans are from the old X Y.

Plane Sections of Curved Surfaces.—The section of a curved surface is obtained in a similar manner by drawing lines—straight if possible—on the surface and finding the points of intersection of these lines with the plane.

Problem 2.—A cone with axis vertical is cut by a plane at right angles to V.P. and inclined to the H.P. Find the true shape of the section.

A number of straight lines, say 12, are drawn on the surface of the cone and their points of intersection with the given plane determined. The problem is thus reduced to that of Problem 1, and the work proceeds in the manner there indicated. A fair curve is drawn through the points obtained. Fig. 50 shows the drawing complete.

It will be noticed that in Fig. 50 the construction for finding α the plan of the intersection of the line V A and the plane P P fails, since *v a* and the projector $\alpha'\,\alpha$ are coincident. In this case a "side elevation" $v_2\,a_2$ of the line V A should be drawn and α_2 projected from α'. The distance of α_2 from $X_2\,Y_2$ is the same as that of α from X Y.

The same problem may be solved by drawing circles on the cone and determining their points of intersection with the given plane. Fig. 51 shows an example worked out by this method. The construction can easily be made out by a careful inspection of the figure.

CUTTING TOOLS.—IV.

By R. H. Smith,
Professor of Mechanical Engineering, Mason's College, Birmingham.

[*Continued from p.* 157.]

HAND PLANES (*continued*).

Guidance of Planes.—We have here quite a peculiar sort of guidance for the cutting motion of the tool.

Behind the tool the surface has been cut down by the thickness of a shaving. In front of the edge of the iron it remains still uncut, and therefore higher than the hinder portion. The flat sole is therefore tilted slightly upwards, the forward end being the higher.

The workman, bearing heavily on the fore end of the stock, causes the front half of the sole to compress the uncut surface of the wood, so that the

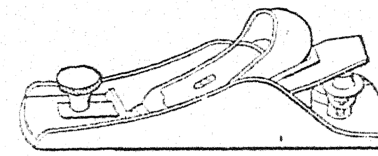


Fig. 10.

forward edge of the sole, instead of being raised clear of the wood, rests upon it. The depth of shaving cut, measured in the uncompressed condi-

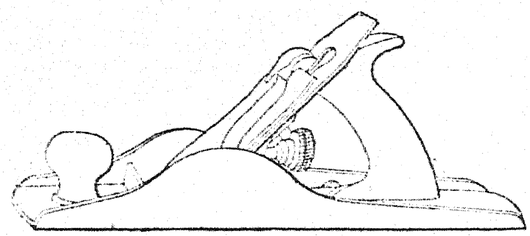


Fig. 11.

tion of the wood, is that of the projection of the edge of the iron below the sole, increased slightly in proportion to the pressure exerted by the workman.

Thus if the uncut surface be already truly flat, then so long as both front and back edges of the sole rest upon the wood, the thickness of shaving will remain constant and the planing will not bring the surface out of truth. But if there be unevennesses, however minute, then when the tool is over the hollow parts the whole or the greater part of the pressure is borne at the ends of the sole, while the iron either does not cut at all, or removes only an extra thin shaving; when, however, it is over a high place, the full pressure comes on the part of the sole near the iron, and this latter takes an extra deep cut, thereby reducing the unevenness.

The pressure put on the material immediately in front of the iron greatly conduces to the clean cutting of the surface. It prevents splitting and tearing of the wood in advance of the tool.

This splitting is farther prevented by the shaving being broken or rather half broken through as soon as it leaves the surface. In examining a shaving from a plane, lines or small ridges are seen running parallel and crosswise, close to each other. If the plane is in good condition and the wood be of even texture, these ridges are spaced the one from the other at very regular distances. If the shaving be bent over, it always cracks along one of these lines. They are seen more easily on thick shavings than on thin, and are farther apart on the thick ones.

This cracking of the shaving is effected when the shaving slides up the edge of the top iron. Holtzapffel seemed to think that this was the chief and indeed the only function of the top iron. This idea is incorrect. It was probably occasioned by the fact that the top iron of the trying plane is placed much closer down on the cutting edge than that of the jack plane, while at the same time the lines of cracking in the shavings from the trying plane are much closer than on those from the jack. But this will be found to result from the greater thinness of the shavings and from the narrower mouth of the former. To test this point, the author closely examined the shavings from a jack and from a trying plane, the mouths of both of which were narrow (the planes being nearly new) and exactly equal. The top iron of the trying plane was put close down to the cutting edge, while that of the jack was set back nearly an eighth of an inch. When both planes took exactly the same thickness of shaving from the same piece of wood, no difference of any kind could be discovered between the shavings from the two, even when examined by a magnifying lens. The cracks were exactly the same distance apart in both. When either plane was set to take a slightly thicker cut than the other, the difference immediately showed in the spacing of the cracks, this being greater the thicker the shaving, whether this came from the jack or the trying plane.

This proves that the chief object in putting the top iron close down to the cutting edge in the trying plane is to keep this edge perfectly steady, so that it may not yield more or less according to whether it cuts over a high or a hollow place. The object is not the more immediate breaking of the shaving.

When an old jack plane with the sole worn so that the mouth was $\frac{1}{4}$-inch wide in front of the cutting edge was used in these experiments, and when very thick shavings were taken, the spacing between the lines of breakage agreed more with the distance of the top iron edge back from the cutting edge than with the width of the open mouth.

When there is a wide mouth to the plane, the setting back of the top iron conduces to splitting in front of the tool, and in the jack it is set back with this avowed intention, because, as has been previously explained, splitting is by far the easiest mode of removing the surface of the wood.

MACHINE PLANES FOR WOOD.

Velocity of Cutting.—If the velocity of cutting be greatly increased, the necessity for applying the

holding down pressure close to the tool edge disappears, because the advance of the tool may be made swifter than the speed at which splitting can possibly take place. This is what is done in wood-planing machines driven by steam or water power.

In these, plane irons precisely similar to those used in hand planes, except that they are without any top iron, are held by screws in a block which revolves at such a speed as to make the cutting velocity of the tool-edges from 4,000 to 10,000 feet per minute, the slower speed being suited to the harder qualities of timber.

The revolving spindle on which the cutter block is fastened is horizontal. The surface of the wood to be operated on is also placed horizontally; or, where different surfaces at right angles to each other are to be worked simultaneously, the largest and most important of them is horizontal.

The bevel of the tools is somewhat shorter than that of the iron of the hand plane; that is, the cutting angle is made larger to give the edge greater strength against the occasional sudden extra resistance caused by unevenness of the uncut surface or by knots. The angle at which the blade is set to the plane of the work is also made greater, namely, about 55° or 60°.

The blades must have a width at least as great as that of the planks to be planed.

A planing machine of Messrs. A. Ransome and Co.'s make is shown in Fig. 12. The boards are fed in at the end of the machine seen at the right-hand side of the engraving. They are first surfaced on the under side by a revolving cutter-block, the end of whose spindle is marked *a* in the illustration. This under surface is next finished smooth by extremely fine shavings being cut off by the *fixed* planing blades marked *b*. At this part of the machine four rollers marked *c* hold the timber down against the upward pressure of these tools.

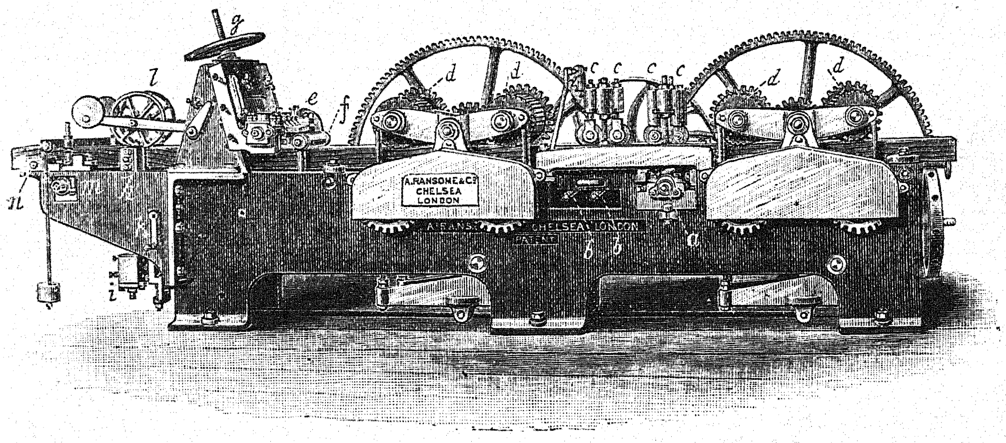


Fig. 12.

The revolving cutter rotates right-handedly so that the blades cut *backwards against* the forward feed motion of the timber. This feed motion is effected by the four-ribbed rollers *d* driven by spur gearing. The boards then pass under the revolving cutter-block *e*, which planes their upper surface, vibration or "chattering" being prevented by the holding down roller *f*. Here the boards slide over a fixed flat iron table, and the thickness to which they are reduced depends on the exact level of the spindle of the block *e*. This process is, therefore, termed "thicknessing." The bearings of spindle *e* are in a sliding carriage, which can be adjusted to the required level by the screw and hand-wheel *g*. This block revolves left-handedly, so that the cutting motion of the tool-blades is again contrary to the feed motion. The side edges of the board are next dressed either plain, or with groove or tenon as may be desired, by the vertical cutter blocks *h*, one only of which is seen in the engraving, the other lying on the hinder side of the machine. This block overhangs (vertically) its bearings, the lower one of which is seen at *i*. These bearings are mounted on a sliding carriage, which can be adjusted vertically by help of the crank-handle *k*. Here the wood is steadied at the edges by the weighted rollers *l*. At *m* is a small extra cutter block on a horizontal spindle, by which a bead or moulding can be put on the under edge of the board, if desired.

Finally at *n* may be clamped fixed planing blades for smoothly finishing the side surfaces already cut at *h*.

The holding down rollers *c* are pressed down by springs whose force is easily regulated by the nuts and screws at top of their spindles. The pressure on the feed rollers *d* is applied by heavy weights, and this also can be adjusted to what is needed up to several tons. These feed rollers are from 12 inches to 15 inches in diameter in different machines.

Fig. 13 shows an enlarged section of one of the horizontal cutter blocks, and its bearings. The block is of cast steel. It carries three cutting blades (sometimes four) clamped in undercut slots by T-headed screws. These blades and also the fixed blades are about $\frac{3}{8}$-inch thick. In the block the tips of the blades revolve in a circle of about 8 inches diameter. With recently improved bearings the speed may be as high as 4,500 revolutions per minute. This gives a linear cutting speed between 9,000 and 10,000 feet per minute, and the rate of feed may be 30 to 40 feet per minute. The bearings are of the hardest gun-metal. To get them exactly in line with each other, the brasses should be first carefully fitted in their cast-iron seats in the sliding carriage; and then, the covers being firmly bolted down, they should be bored out in a boring lathe at one setting. To allow of successful running at this high speed without heating, the spindles must fit the bearings very exactly; the bearings must have a length of four to six diameters; the two bearings must be in very accurate alignment; vibration must be entirely prevented by the framing being stiff and massive; the lubrication of the bearings must be copious, and especially regular; the feed of the timber must be very steady, not in the least degree jerky, and the steadying rollers must entirely prevent chattering; and lastly, the block and the blades must be very exactly balanced, as otherwise the centrifugal force of the unbalanced parts will produce vibration and wear.

If the plank be fed forward at the rate of 40 feet per minute and the spindle make 4,400 revolutions per minute, the advance per revolution will be $\frac{40}{4400} = \frac{1}{110}$ feet $= 0{\cdot}11$ inch. If there be three blades in the block the depth of each cut will therefore be 0·04 inch; and with four blades it would be no more than 0·03 inch. In consequence of the combination of this very small depth of cut with the very high speed of cutting, these machines plane up wood surfaces with a high degree of smoothness and "finish."

Tenoning and other Machines.—There is a large class of tenoning, tongueing, grooving, beading, match-boarding, dove-tailing machines, etc., which are all constructed on very much the same principle as that of the last described. Their appearance is often much complicated by their being arranged with several different tools to do as many different kinds of work, all mounted on the same framing.

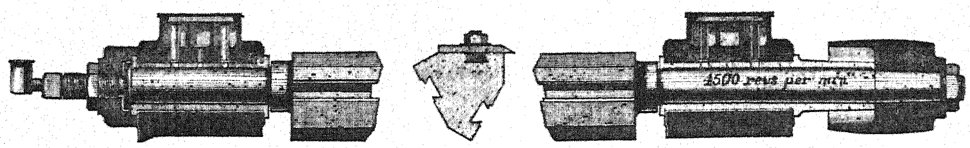


Fig. 13.—Cutter Block and Spindle for 14-in. Trying-up Machine.

In America, where so much more timber is "converted" than here, and where manual labour is much more expensive, the designs of such machines show frequently great ingenuity and skill in arrangement of parts.

SAWS AND MILLING MACHINES.

A class of machine tools very much resembling in principle those last dealt with includes saws for wood, saws for iron, and milling machines for metal.

Saws for wood of the commoner sorts differ from the planing machine in having their cutting chisels made all solid together in one piece. This distinction, however, can no longer be made as a general one between saws and other machines, because large modern circular saws sometimes have "inserted" teeth. There remain two essential distinctions, which separate saws for wood and iron from planing machines, but which do not apply to milling machines. These are, firstly, that the object of the tool is not to flatten and true up a surface, but to *separate* a block of material into two distinct parts; and, secondly, that in consequence of this being the object, the teeth and blade on which they are set are made as *narrow* as they can possibly be made consistently with their having sufficient strength to resist breakage. To obtain a maximum of strength with a minimum of width of face, the thickness of the tooth or cutting chisel, measured in the direction of the cutting motion, is made as great as practicable.

Saving of Timber by Thin Saws.—By making the width of face small, two objects of very great importance are attained. In the first place as small an amount of material as possible is converted into saw-dust and thereby almost entirely wasted.

This waste in saw-dust does not appear at first sight to be of extreme importance when one watches only a few planks being cut. But when one considers that this waste is repeated millions of times in the course of a year in a single saw-mill, the absolute necessity of economy in this direction becomes evident enough. If, for example, a 14-inch square log is to be converted by sawing into $\frac{5}{8}$-inch planks, if the saw cut away $\frac{1}{16}$ inch only between each plank, twenty planks will be got from the log; if it cut $\frac{1}{8}$ inch away only eighteen boards $\frac{5}{8}$ inch thick can be got out of it; and if $\frac{3}{16}$ inch be lost in saw-dust, then only seventeen boards will be obtained. Thus in the first case about 9, in the second 17, and in the third about 23 per cent of the timber is lost in the shape of saw-dust.

If these logs were 12 feet long, then in the first case, there being twenty-one cuts, each 14 inches deep and $\frac{1}{16}$ inch thick, there will be more than $1\frac{1}{2}$ (exactly $1\frac{17}{32}$) cubic feet of timber converted into saw-dust for every log. In the second case there would be $2\frac{3}{4}$ cubic feet lost; and in the third $3\frac{15}{16}$ cubic feet would be the waste in saw-dust.

If now we suppose that a single saw-frame cuts up fifty of these logs per day, and works 250 days per year, the losses per year in the above three cases would be 19,150; 34,350; and 49,150 cubic feet of timber per annum. Taking this at the price of 2s. per cubic foot, which is a fair average for yellow pine, we find that the above three yearly losses are represented in money by £1,915, £3,435, and £4,915. This example serves to show the extreme importance of saving by making as little saw-dust as possible. Although £2,000 or even £5,000 may be only a small fraction of the gross annual expenditure at such a mill, it may still be a very large fraction of, or even more than the whole of, the possible annual *profit*.

Saving of Power by Thin Saws.—Secondly, it is almost self-evident that the power required to drive the saw becomes greater in simple proportion to the width of the cut it takes. To save horse-power in the steam or water driving engines also, therefore, thinness of the saw-blade is of the greatest utility. Even in hand-saws, the difference in fatigue to the workman is very speedily recognised by anyone who tries saws of different thicknesses on the same wood.

In the hand-saws used in England the cutting stroke is a push outwards from the shoulder of the workman. This mode of using the tool has been perpetuated by the Anglo-Saxon race in the United States, Canada, and the British Colonies. The blade of the saw is thus thrown in *compression*, and in order that it may have sufficient stiffness to prevent it buckling, it requires to be made far thicker than if it had to transmit the same force in tension only. On this account chiefly, also, English saw-blades for hand-work are (and require to be) made of a much better quality of steel than would otherwise be necessary.

In Germany, Italy, and most of the European Continent, as well as throughout the chief peoples of Asia, hand-saws are used in tension, the cutting stroke being a pull towards the chest of the worker. In consequence, the blades are made very much thinner than those of English saws, less material is converted into saw-dust, and less exertion is required for a given rate of cutting.

DRAWING FOR CARPENTERS AND JOINERS.—IV.

[*Continued from p. 161.*]

JOINTS IN CARPENTRY AND JOINERY.

FIG. 42 exhibits two methods (*a* and *b*) in which timbers can be united at right angles to each other when they are not to cross. These illustrations are too plain to need any explanation.

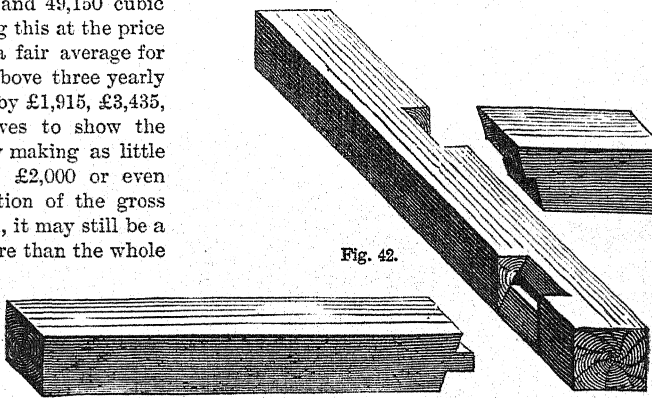


Fig. 42.

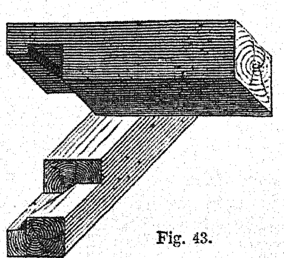


Fig. 43.

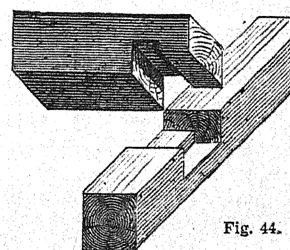


Fig. 44.

Fig. 43 is one of the numerous methods for uniting timbers at an angle of a building by means of a dovetail joint, by which means the end of each is locked into the end of the other.

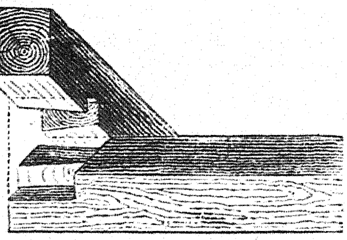


Fig. 45.

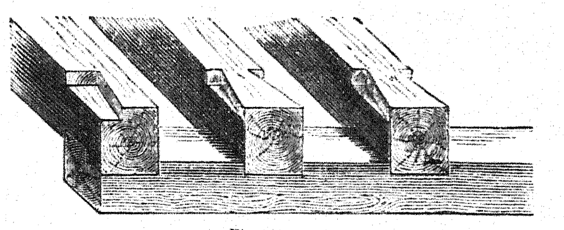


Fig. 47.

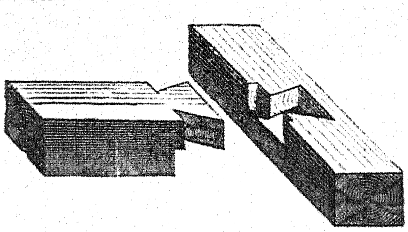


Fig. 46.

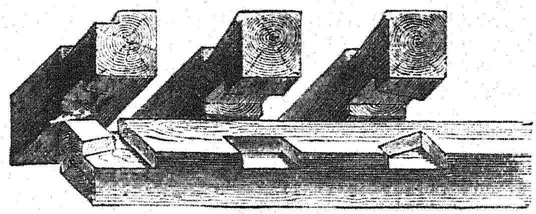


Fig. 48.

Fig. 44 shows another method by which one timber is notched on to another. This is a very good system, for the upper holds as it were by a hook, which acts against a shoulder in the lower. The upper is thus prevented being drawn inward by weight placed upon it, and the lower is strengthened against any pressure which might tend to force it outward.

Fig. 45 is a joint of a similar character, a dovetail being employed in this case, which in Fig. 46 is further secured by an additional shoulder.

Figs. 47 and 48 are methods by which the ends of timbers are firmly attached to beams or wall-plates on which they rest. The upper surfaces are shown as cut for the reception of an upper timber to further bind them together.

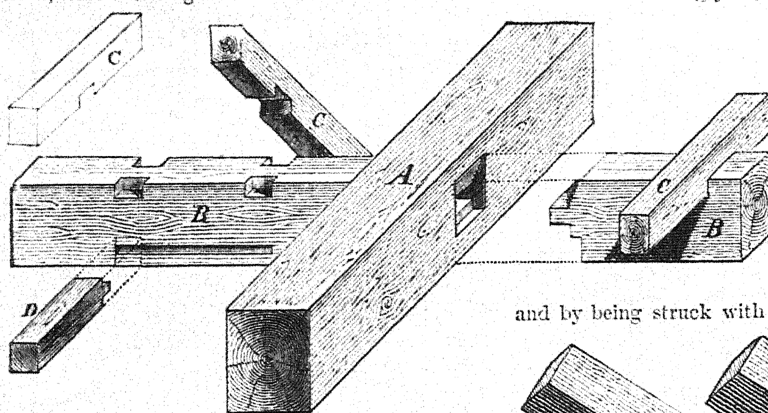


Fig. 49.

Fig. 49 is the Continental mode of constructing framed flooring. Here A is the girder, B B the bridging-joists, C the floor-joists. Here it will be seen that the ceiling-joist, D, is not notched on to the under surface of the binders, but is inserted by a tenon and groove. The groove or slot being made longer than required, the ceiling-joist is placed slantingly across between two binders, its ends being in the opposite ends of the grooves: and by being struck with the mallet it is forced into its proper direction at right angles to the binding-joists.

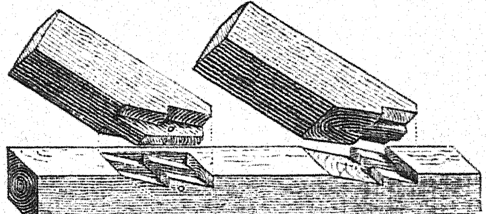


Fig. 50.

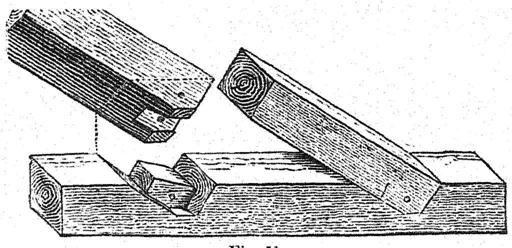


Fig. 51.

Figs. 50 and 51 show four different kinds of oblique mortises. The principles on which such joints are worked have been given in "Building Construction" in connection with figures.

Fig. 52 shows the method of uniting boards *a b* in a flat surface, called *Dowelling*. The edges to be joined having been very accurately planed, holes are bored, pins as at *e* are glued into the one, and the projecting ends being inserted into corresponding holes in the edge of the other board, unites them firmly—the edge of the board *c* and the end of the pin being glued. Square pieces of hard wood, or dowels, are often used in the place of pins, and are shown at *d*.

Fig. 53 is a method frequently adopted in floor-boards and panelling. It is called *Rebating*, and consists in planing away half the thickness of the edge, so as to leave a ledge standing; all the boards being thus rebated, the ledge left on the one fills up the rebate, or "abated" edge of the other. This will be clearly understood on referring to the illustration.

Fig. 54 is the method of joining boards called "ploughed and tongued." In this case a groove is planed in the one edge, and a tongue left (by planing away the angles) at the other end of each board; the tongue of the one then fits into the groove of the other. In very good work it is usual to plough *both* edges, and *insert* a separate tongue. This tongue is formed of strips cut the cross way of the wood, as shown in Fig. 55.

Fig. 56. This method consists in working grooves across the back of the pieces *a*, and forcing rabbets into them, as *b b*. The bottom of this groove is flat (A), and its sides slant inwards towards the bottom. The sides of the rabbet are also cut slantingly, and a joint is thus formed called the "dovetail notch."

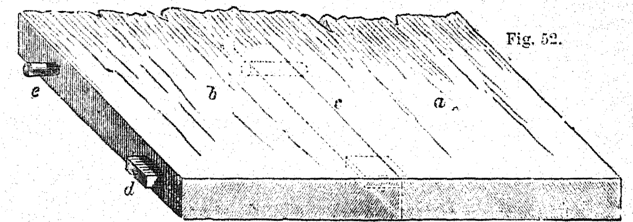


Fig. 52.

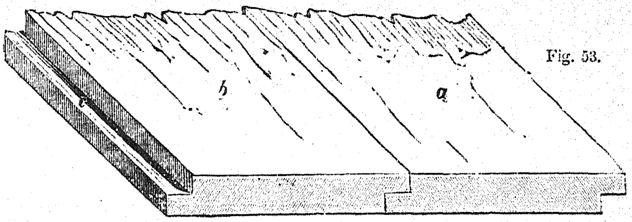


Fig. 53.


Fig. 54.

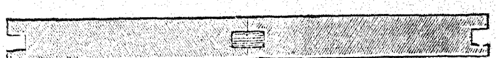


Fig. 55.

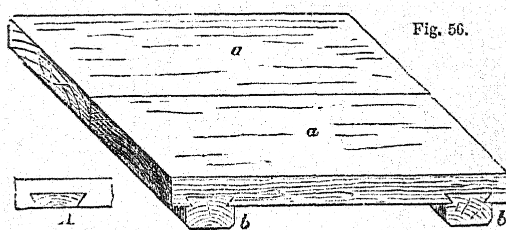


Fig. 56.

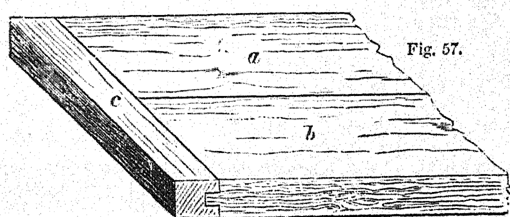


Fig. 57.

Fig. 57 is an illustration of the method of clamping the ends of boards, *a b*, by tonguing the board and ploughing the piece which is to cross it, *c*. Sometimes, instead of bringing the end of the cross-piece flush with the edge of the board, it is cut off at an angle, the board being cut correspondingly to admit of the insertion. This last method is called *mitre clamping*.

Fig. 58 shows a very common method of joining up a flat surface by means of framing and panelling. A groove is run in the edge of the

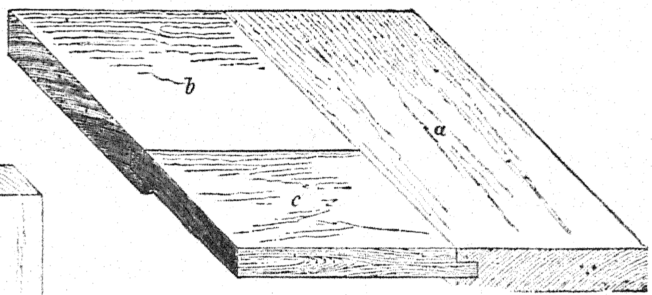


Fig. 58.

Fig. 59.

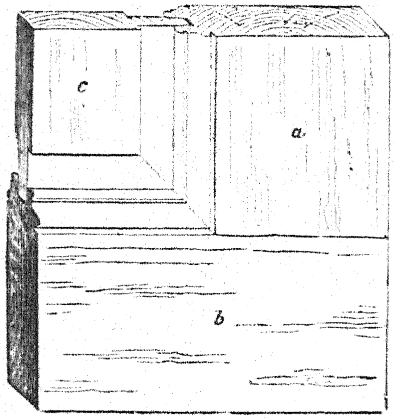


Fig. 63.

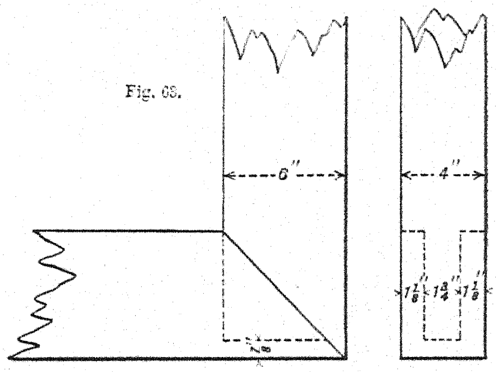
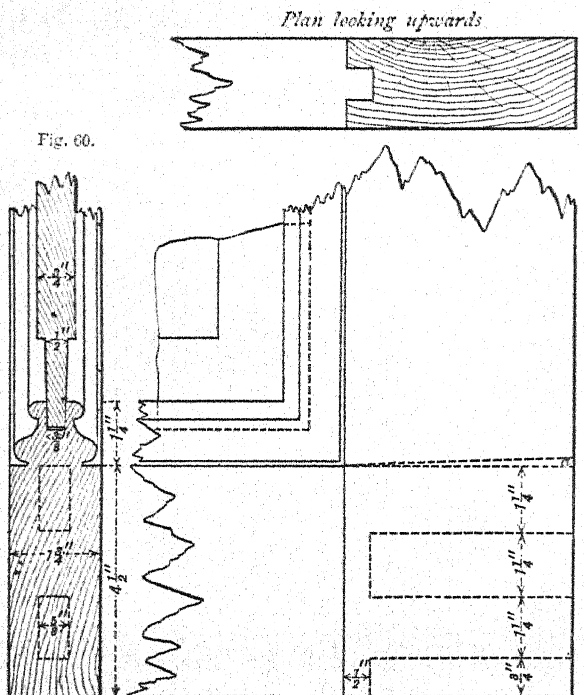
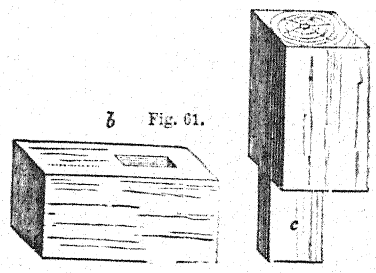


Fig. 60.



b Fig. 61.



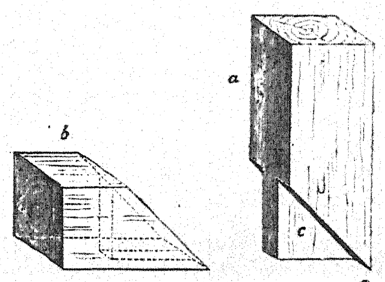


Fig. 62.

frame, the edges of the panel are rebated, and the whole brought up flush.

Figs. 59 and 60 show a portion of a panel inserted into a frame where a flush surface is not required, as for example in a common room door. The double mortise and tenon joints at the corners of the frame are secured by thin wooden wedges, one of which, *a*, is shown in the elevation (Fig. 60).

Fig. 61 represents one of the many methods employed for angle joints. It is the simple mortise and tenon, a shoulder being left on the outer side of the tenon by which the one piece is secured against being forced out of perpendicular.

Figs. 62 and 63 show another method, which is accomplished by means of a mitre, part of the wood being left as a tenon at the end of the one part, which is inserted into the mortise at the end of the other. A pin is then passed through the whole.

PHOTOGRAPHY.—IV.

By T. C. Hepworth, F.C.S.

[*Continued from p.* 178.]

BACKGROUNDS.

An important item of the studio furniture is the background. Most photographic studios have a variety of these on rollers hung at the end of the apartment, and so fitted that any one of the set can be rolled down at will. Some of the backgrounds now supplied, notably those of French origin, are quite works of art in which the artist has obtained the maximum of effect with the minimum of detail. Before choosing a background the student would do well to spend some time in our National Gallery, or at some other collection of good pictures. He will then notice that our best artists painted backgrounds simply with a view to giving the figure or figures before it relief by means of light and shade. Taking this hint then, we may feel sure that the photographer will do well to avoid the ornate background crowded with detail in the shape of landscape or architectural adornment, and trust to one which is either quite plain, or better still, one which is graduated. A special material in various tints of suitable width is now made for plain backgrounds, and can be purchased at so much per yard. A woven material, which is graduated, has also been recently introduced. If the photographer be an artist, he will be able to paint backgrounds to suit his own tastes, should he fail in purchasing what he wants. Such a background should be painted in distemper, or in flatted oil, a neutral tint being employed. It is clear that any method of painting which leaves a shiny reflecting surface is inadmissible.

Under the name of accessories come a great variety of objects, furniture, and the like, which are made for the use of the photographer, and which can be bought at numerous establishments devoted to his interests. It must be confessed that too many of these are things to be avoided. In the early days of photographic portraiture, marble columns, elaborately decorated cabinets, chairs with sprawling legs, which looked as if they had been designed for any purpose than that of sitting upon, were common enough. And curiously enough they were affected by those photographers in second-rate neighbourhoods whose clients were not those who were commonly accustomed to such luxurious surroundings. But happily it was well understood that these things were merely photographic embellishments. Certainly their like was never seen nor dreamt of outside the confines of a photographic studio. Times have changed for the better. The establishment of schools of art all over the country has naturally had a certain influence on photographers as upon the rest of the community, and "accessories" have benefited by that influence. But the things are still made, and can be purchased by the unwary, for the ordinary worker, if left to work in a certain groove, will go on working like an automaton, and will not change his methods until the superiority of some other man's productions—very often that of a foreigner—will give the hint that he must put his house in order.

At a photographic exhibition at the Crystal Palace accessories of a very different nature were shown. These were apparently made of canvas treated with plaster, and the design as well as the workmanship were evidently due to an artist. Coloured a dull grey, the artist had reproduced the forms of old cabinets, balustrades, and the like with wonderful fidelity to the originals. And it must be remarked that he had not depended upon paint for his effects so much as upon rough surfaces and moulded projections, which provided their own lights and shadows. This work was, in a word, of the highest class and of a nature which few could equal without training and long practice.

In the absence of such accessories as these, the student will do well to content himself with such surroundings as are found in an ordinary dwelling-house, and he may feel sure that his portraits will be the more natural and pleasing the more he confines himself to these simple adjuncts. The professional photographer must indeed study simplicity if only for the reason that he has very little control over the dress of his sitters. Ladies will often come to a studio more for the purpose of being photographed in a particular gown than with the idea of getting an artistic portrait, and when

the said gown is of a loud pattern, or with trimmings which are violent in their contrast with the rest of the dress, the photographer, although he be a gifted artist, has a hopeless task before him.

EXPOSURE.

The task of judging accurately the necessary time for which a photographic plate must, under varying conditions, be exposed to the action of the lens is one of the first, if not the chief, difficulties which assail the beginner. In a studio, this initial difficulty is more quickly surmounted than under other circumstances, for the sitters are in one fixed position, they are illuminated by a light which does not vary much except with the time of day and under different conditions of weather; and with a short experience under the glass roof the operator is able to produce negatives which seldom exhibit any fault due to either under- or over-exposure.

The studio exposure will not only vary with the time of day but also with the time of year, and of course according to whether the sun be obscured by vapour or be placed in a cloudless sky. There is also another point which does not generally receive the attention it deserves, and that is the way in which the value of the light is modified by the presence of clouds. It is often the case that under certain conditions far more light is reflected towards the studio on a cloudy day, that is, when there are a plenty of white cumulus clouds in the sky, than when the sun is unshielded and giving a constant glare.

This difficulty of judging the correct exposure is naturally much increased when the photograph is taken out of doors, for here the difference of character of every subject must in some degree, and often to a considerable extent, affect the question. We may, for instance, have at one moment to deal with an open expanse of country, or a marine view, which possibly may only require an exposure of half a second. The next picture taken may possibly be a woodland scene so screened with foliage and shrouded in darkness, and with the light so filtered through a yellow or green canopy of leaves, that the lens must be uncovered for several minutes. The writer has in his possession a number of negatives of which the particulars under which they were taken have been carefully noted; one of these, a woodland scene in the Isle of Man, received an exposure of three minutes on a sunny day in June. Another similar scene, taken on the Lynn, in North Devon, required an exposure of double that time; while a very dark scene in the New Forest was not impressed upon the plate until fifteen minutes had elapsed from the uncovering of the lens. For interior views, where darkness is generally much more accentuated than it can be under sky light, the exposure may sometimes extend to two or three hours.

A great number of tables, called exposure tables, have been printed of late years. These tables are decidedly useful to the beginner, for they will give him some guide as to the exposure necessary for different kinds of subjects; and he will also learn from such tables how the light of the sun varies in actinic value according to the time of day or the month of the year. Such tables have been compiled with great care, and there is no doubt that they form a useful guide to comparative exposures; thus we ascertain at a glance that a view of sea and sky, constituting the very brightest things in nature with the exception of the sun itself, must receive a less exposure than any other kind of photographic picture. An open landscape will, roughly speaking, want three times that exposure, while a landscape with heavy foliage near to the camera must have a still more prolonged time to impress its image on the plate. Then we come to views under trees, in which, as we have seen, exposure is a very variable quantity, and so on to well lighted and poorly lighted interior views. But we would strongly advise even the beginner in photography not to rely too steadfastly upon any of these exposure tables except as a matter of education. The best guide of all is that of experience. The photographer who has mastered his art will be able to tell by glancing at the ground glass screen of his camera, and noting the amount of light by which it is illuminated, how long to uncover his lens, and this is the proficiency at which the tyro should aim.

Exposure being such a very important part of photographic work, we advise the beginner not only to study the tables referred to, but also to test their value by actual work in the open air. But he would do well in all these experimental essays to confine himself to the use of one particular stop in his lens. He will thus at once do away with a great many difficulties in which he would find himself floundering were he to avail himself of all the different stops provided for his lens successively. When he has had experience in exposing a large number of plates under different conditions of light and subject, it will be time for him to see what variations can be brought about by the employment of the other stops with which his lens is provided.

The exposure of a plate and its development must always be associated together. The most careful development goes for naught unless the exposure has been approximately correct. We may

lay down the rule that an under-exposed plate will never yield a good picture, and, unless such a negative is that of a subject for which there will be no opportunity of getting another one, it is far better to destroy it at once than to go on dealing with a thing which can never produce satisfactory results. An over-exposed plate can, on the other hand, be saved by judicious development, but it need hardly be said that the best result of all is obtained from a negative which is normal, that is to say, which has been what may be called correctly exposed.

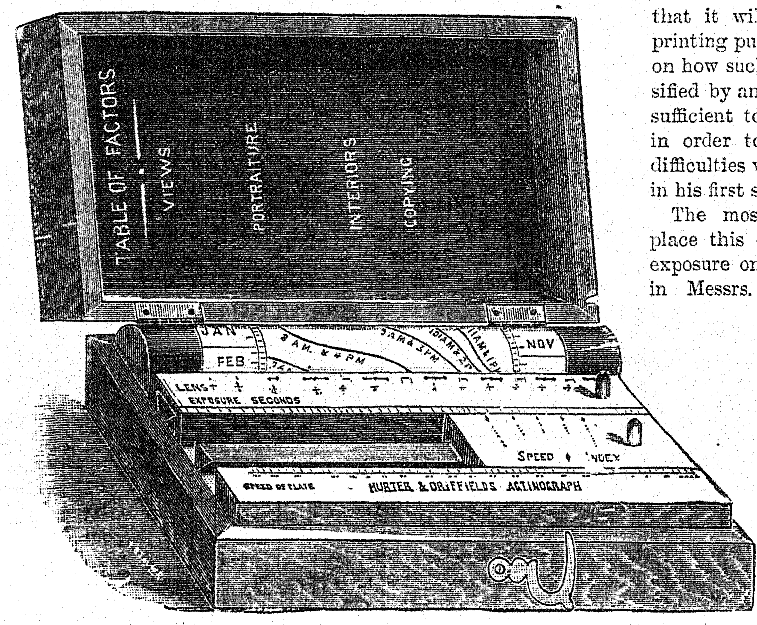


Fig. 30.

The beginner will soon learn that a long exposure produces a peculiar softness and harmony which is unattainable on a plate which has received too short an exposure. But he will not so quickly ascertain the difference in appearance between over-exposure and under-exposure as it would seem that he ought to do. A negative which has been very much under-exposed is soon detected during development by the number of white patches which remain on the plate after the portions which have received the greatest access of light have been blackened, and such white patches will, in the finished negative, if it be thought worth while to finish such a negative, represent clear glass, and bring about violent contrast in the printing frame. An over-exposed negative, on the other hand, will show a general darkening all over the surface of the plate with no white patches whatever, and, the finished negative will exhibit an image full of delicate detail, but so thin and veiled that it will be almost useless for printing purposes. We shall see later on how such a negative can be intensified by an after-operation, but it is sufficient to refer to the matter here in order to point out some of the difficulties which assail the beginner in his first steps with the camera.

The most successful attempt to place this question of photographic exposure on a scientific basis is seen in Messrs. Hurter and Driffield's Actinograph, of which an illustration is given at Fig. 30. In this instrument there are four scales, which correspond with the four factors: light, time, lens, and speed of plate. This clever little instrument will indicate exposures from one minute in duration to the $\frac{1}{20}$th part of a second. The scales are movable and readily adjusted to one another according to light, time of year, time of day, etc., the approximate exposure being quickly read off. Full directions accompany the instrument, which is small enough to be carried in the pocket without inconvenience.

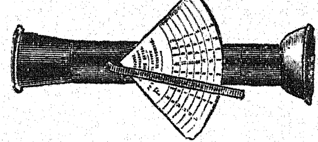


Fig. 31.

The Tylar-Pickard exposure meter is the type of another class of instrument which gives on a scale the approximate exposure *required* on any given subject. In this instrument (Fig. 31) a movable lever crosses a fan-shaped scale, and this lever is moved with the finger while the operator looks through the tube at the picture to be photographed. He moves the lever, which increases an orifice at the end of the tube, until the light admitted is just sufficient by which to read certain letters which are printed within upon a glass screen. When

these letters are just visible, he removes the instrument from his eye, and sees by the position of the lever—which now assumes the *rôle* of index hand—what exposure is required with any particular diaphragm with a plate of ordinary sensitiveness.

WATCH AND CLOCK MAKING.—IV.

By David Glasgow,

Vice-President of the British Horological Institute.

[*Continued from p.* 164.]

CHRONOMETER AND WATCH MAKING (*continued*).

Adjusting-rod.—The adjusting-rod shown in Fig. 6 is somewhat different from the ordinary one used by finishers for testing the pull of mainsprings, etc. In addition to the sliding weight, the jaws which grip the squares can also be shifted, being fixed at any required distance along the rod by means of a thumb-screw at the back. This enables it to be used for almost any spring, from the weakest to the strongest.

After adjusting the mainspring, the adjusting-rod should be put on the fusee square before the weight is shifted, and the great wheel held in the hand in such a position that the weight will draw the pin in the maintaining spring to the other end of the slot in the wheel through which it projects. If the weight of the rod does not draw the pin forward, the maintaining-power spring is too

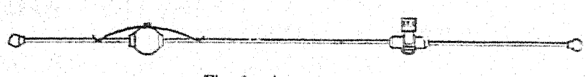


Fig. 6.—Adjusting-rod.

strong, and must be weakened: the mainspring must be strong enough to draw the maintaining-power spring as far as the slot will let it go when the power of the spring is pulling on the fusee. A brass cap is let on to the fusee square to keep dirt from getting into the hole when the piece is wound, and a pipe is generally screwed on to the plate round the winding square, and let through the bottom of the brass box, to keep dirt and damp from the chronometer.

Finishing the Wheels and Pinions.—The pillar plate has a circle cut out, and a bar screwed over it on the dial side to receive the bottom and seconds pivots of the third and fourth wheels: this arrangement enables the third wheel to be run under the centre wheel, and prevents the seconds pivot from being too long. The fourth pinion must be pivoted close to the bar, and must have a deep hollow cut in its face to prevent the oil from being drawn from the pivot; the third wheel must be kept free of the centre wheel; and the pinion must have a hollow cut in its back or rivet, as must also the centre pinion.

All the wheels have to be polished. If they are true on the sides, they are first stoned with a smooth Water-of-Ayr stone on a cork until they are quite flat, and then placed in the turns and polished circularly with an ivory polisher, and a paste made by rubbing two pieces of blue-stone together with a very little oil, and finished with a slip of boxwood and a few rubs with a piece of willow at the last; if the willow is used for too long a time, the arms of the wheels will be rounded.

Although polishing the wheels is the usual way of finishing them, stoning them very flat and smooth and electro-gilding them will give them a much nicer appearance, and keep the brass from tarnishing.

The pinions and arbors are highly polished: some finishers burnish the arbors, but a high polish can be got very quickly with a zinc polisher and diamantine.

The faces of the third and fourth pinions are finished with the ordinary facing tool, but as the large pivot on the centre arbor precludes the use of such a tool, it is faced square down to the arbor; the pinion is placed in the turns, and small turns that fit into the rest holder carry a roller mounted on an arbor; this roller is brought to bear against the face of the pinion, and the pinion is rotated backwards and forwards with a bow. The roller first used is steel, to bring up the face flat and square, after which soft metal rollers are used for finishing.

Jewelling.—The third and fourth holes are usually jewelled, although some makers object to jewel these holes, as the pivots are apt to become black; but if jewelling is indispensable in the escapement holes, it is also necessary here, and if the holes are good and well made, the pivots will not wear.

The fourth wheel hole in the upper plate should be jewelled with an endstone, although it is seldom done, as a pivot of equal size is stronger if conical than one with a square shoulder, and the pivot will run with less friction on the end than on its shoulder. The oil also keeps better in a covered hole.

Spotting the Plates.—The spotting of the plates is a branch in itself: it is done in an engine resembling a wheel-cutting engine.

Watch Finishing.—The various operations that have hitherto been combined under the name of watch finishing I have to some extent treated of separately, for I think that, if ever watchmaking

resume its former proportions in England, some more economical and rational system must be pursued in manufacturing than that now in vogue. No better way could be devised of making a young man a thoroughly practical watchmaker than by apprenticing him to a finisher first, and afterwards to an escapement maker. But the time occupied in waiting for work that must be done by others, such as jewelling, engraving, gilding, etc.; the diversity of the work—from pivoting and planting the barrel and fusee to making and planting the stud and index, etc.; and the tools and appliances necessary to enable one man to do these things in the best manner are so considerable that it has not been possible for even the most competent workmen to obtain sufficient remuneration for the time and labour expended on the best work.

Testing the Wheels.—The first work is to get the wheels ready for gilding, and it frequently happens, in movements that are not of the best quality, that they require to be thinned; in that case they should be placed in the frame and the space for them noted. I have often found finishers thinning wheels from habit when there was no occasion for their doing so.

The pinion arbors must be shortened and the pinions and wheels got true; the wheels must be made perfectly true on the sides, square and flat (first on a cork with a piece of Water-of-Ayr stone and afterwards rubbed circularly in the turns): and hollows must be cut in the wheels to permit of the rivets of the pinions being polished without touching them when they are gilt. It is sometimes better to make the lower pivot on the centre wheel arbor before the wheels are gilt, as then the barrel and fusee can be worked into their places.

Running in the Wheels.—The centre pinion has an arbor fitted into it projecting at each end far enough to put a ferrule on it; a deep hollow is cut in the back of the pinion, and the pivot made as close to the wheel as possible. The hole in the plate should be well chamfered and a turned stopping of good brass put in it, the stopping being allowed to project on the dial side of the plate: the centre wheel should always be kept a little below the plane of the plate, to give it sufficient freedom from the barrel and great wheel: the fusee and balance being put into the frame, it will be seen if there is sufficient freedom between them. If the balance is a plain one, and is quite free of the fusee brass, the chain will be free also, but a compensation balance should have more room allowed it, as the rim may be bent after it is cut by careless handling; if the movement is right in this respect, the fusee can be pivoted and planted. The barrel hole in the pillar plate need not be stopped if the barrel is a proper height in the frame, and a sufficient distance from the third wheel arbor and the great wheel. The upper fusee pivot should be as long as possible. Movement makers do not leave it long, as it is a common practice to cut and polish a hollow in the fusee arbor; but there is not space for this with a long pivot, as there is a hollow cut in the reverse side of this shoulder in the rachet wheel to admit the short projecting pipe of the great wheel. Since, then, there is not thickness enough for a hollow on both sides and space for a long pivot, it is much better to leave the shoulder square and turn the fusee piece sloping from the hole to make the bearing light, or take a large corner off the shoulder, polishing the slant, giving the required bearing as with other square pivots. It is customary to polish the inner and outer edges of the fusee cap before snailing it. The inside edge, after being turned to the required angle, is polished with a tool similar in principle to an ordinary pinion facing tool, but turned or filed to fit the angle or edge of the cap: the outer edge is more difficult to do; it is always polished, even in common watches, but there is no reason why it should be, as it is not always ornamental. The outer edge being sloped off in the turns till its edge comes to the plane of the top part of the brass cone, is polished with a broad polisher, one side of which resting on the brass, enables the edge of the cap to be polished quite flat: the back of the hook is filed to a corresponding edge and polished on a cork. Some finishers take out the arbor and polish it all upon a cork.

The pin-hole in the collet and arbor should be broached until it is sound with the fusee together, and, if the wheel and collet are too thin to bear reducing to give the necessary freedom, a piece of tissue paper placed between them while the hole is broached will ensure it. This freedom of the great wheel is a point generally neglected, and is of much more importance than the polishing of the edges of the cap.

The Top Plate.—The depth of the great wheel and centre pinion being determined and marked, and the stopping for the fusee hole put in, the top plate should be turned out for the fusee piece in the following manner:—

Place the pillar plate in the mandrel with the centre in the fusee hole, and peg the hole (pegging the hole is the only method by which a perfect upright can be obtained in the mandrel, and is the usual way of getting it). Take a long peg and cut a fine point to it, and, withdrawing the mandrel centre, place the point of the peg loosely in the hole. Then by bringing the turning rest up to about an inch from the plate, level with the hole,

resting the body of the peg on it, and gently turning the mandrel, it can be seen whether the hole is in the centre exactly; if it is not, the end of the peg projecting over the rest will move up and down, when the dogs must be slightly loosened, and the plate tapped gently until the hole is in the centre.

When the hole is right, tighten the dogs, screw on the top plate, and turn out the place for the fusee piece. An exactly similar course must be followed in putting in the holes in the top plate for the centre wheel and barrel; but the upright of the centre wheel is of so much importance that a hollow stopping should be put in, and the inside of the hole turned out with a fine cutter in the slide rest of the mandrel, to nearly the size of the pivot. It may not be requisite with a good mandrel to peg the hole before turning out the place for the fusee piece, but it is quite necessary to do so when turning out the pivot hole in the piece itself.

The Barrel Arbor.—If the pivots of the barrel arbor are of the proper shape, the pivots and holes will only require smoothing, and the barrel freeing on the arbor. Instead of adopting the usual course of turning away the bosses in the barrel and cover to reduce the rubbing surfaces, a deep hollow should be turned, and a shoulder formed on each side of the arbor of a sufficient width, and the bosses should be left on the brass as large as possible. It has not been the practice to snail the barrel arbors of fusee watches, as there was no trouble with the adjustment of the mainspring, English springs being tapered and generally filed thin at the eye, but the arbors should be snailed (and they probably will be now by the movement maker), and the hook should not project beyond the thickness of the spring.

Hooking in the Spring.—A spring of the proper length and strength being fitted to the barrel, it should be hooked in as follows:—With the spring in the barrel, drill a small hole in the barrel a little nearer to the bottom than to the cover, so that it may be in the centre of the inside of the rim, and within half an inch of the end of the spring; the drill will mark the spring. Remove the spring from the barrel, and broach the hole to nearly the size it is intended to leave it at an angle of 45°; file this hole with a small square file, having a safe edge, until it is oblong, and, when it is of the required size, finish it with a drift. If the hole is in the middle and has not been drawn to either side of the barrel by filing it, the end of the spring can be softened, as far only as the hole for the hook, until it is a light blue colour, but it should not be made softer: the hole is drilled by gripping the spring against a piece of wood or brass in a small hand-vice.

The hook should never exceed one-third the width of the spring, a larger hook unnecessarily weakening the barrel and holding no better. A piece of rectangular steel is fitted to the hole in the barrel, and a mark is scored on it with a sharp point along the inside of the barrel. This mark will give the angle at which the shoulder should be made; if the angle is less than 45°, the hook will probably draw out if the spring is fully wound round the arbor. The pivot on the hook is often made by filing, but it is much better and quicker to make it with a cutter. As the strain comes on the back of the hook, the pivot should be kept as near the front as possible. The cutter is a piece of steel with a hole drilled in it and fine teeth cut on its face; it may either be a piece of wire with a ferrule on it, or it may be fitted to a drill stock. In the latter case the hole should be broached from the back to enable the cutter to free itself, but as the pivot need not be long, this is not imperative: the cutter should be slightly convex on the face to ensure a firm seat for the hook when riveted. A point or centre being left on the steel which is to form the hook, a few strokes of the bow will form the pivot, and the angle of the hook when the pivot is made should correspond with that of the hole in the barrel. The pivot is fitted by broaching and chamfering the hole in the spring, and riveted by gripping the steel in a blunt pair of nippers and screwing them up in a vice: the rivet should be left long, and made with a few strokes of rather a heavy hammer. There is a good deal of strain on this hook, and for that reason the attempt (generally a failure) at using a hook a second time should never be made.

About three-eighths of an inch of the spring should be left beyond the hook, and this end must be filed away to a knife edge, the thinning to commence at the hook. If the spring is left the full thickness at the end and an unusual strain is put upon it, it will break across the hole where it is weakest, or the hook will draw out. Most watch jobbers know this, and generally make the end of the spring so soft that it bends, and all the advantage of a rigid attachment is lost.

If the spring is fitted to a new barrel, the hook can be filed down from the outside of the barrel, and finished on an arbor in the turns; if, however, the barrel is gilt or polished, the hook must be finished before it is finally put into the barrel; it is brought to height by trying it in the hole from the outside, and filed down and finished on a cork; the hook must not project beyond the barrel. If there is any difficulty found in getting the height of the hook by trying it from the outside, the thickness of the rim and mainspring can be measured

separately by a *douzième* gauge: the thickness of the two together will be the thickness of the mainspring and hook. This is the best way of hooking in the mainspring of a fusee watch.

As the springs are now nearly always fixed in going barrels with a steel hook in the barrel, some system should be observed in making them. In English watches the greater part of the mainspring is brought into action, and, as no pivoted brace is used, the hooks must be made more secure, otherwise the spring will either slip off or pull the hook with it.

Adjusting the Chain.—When the spring has been hooked in, the fusee piece made and planted, and the fusee and barrel run in, the chain should be attached and the stop work filed up and adjusted. Care must be taken that the hole in the barrel for the chain hook be placed so that the chain will be just free of the plane of the top plate; the hole may be drilled anywhere in the barrel, provided a little is filed out of the cover to free the end of the hook should it project into the sink, which it generally does. If the chain is too far from the plate, the second turn will probably ride on the top of the first, hence the necessity of keeping it as close to the plate as possible, and to avoid this riding of the chain, it must not be left too long. The barrel hook should come to the outer edge of the top plate when the chain is wound up.

The hollow in the stop may be filed out to nearly its proper thinness (*see* Chronometer Finishing, page 164), but in no case should this process be considered sufficient.

If watch finishers, or even examiners, had thoroughly understood the uses of the adjusting rod and freely used it, half the faults that have been found with the fusee watch would have been avoided. It is not that the actual adjustment of the mainspring is of such importance at this stage, but, with the fusee and barrel only in the frame, any fault that may afterwards give trouble can be seen and removed. If the chain does not lie square on its edge on the barrel, it should not be used, as no filing will make it do so: it ought to lead freely into the grooves of the fusee, and not touch the stop the turn before the final one, and, when it does touch it, it should bring it close to the top plate as the hook of the fusee cap comes to it: at all other times the stop should be quite free of the hook, and not rise high enough for the end of it to come in contact with the chain on the fusee.

If the sinks for the barrel and fusee in the top plate are turned deep, it is sometimes difficult to prevent the chain from riding on the barrel hook: to avoid this, accordingly these sinks must not be turned too deep. Too much endshake to the barrel or fusee will also cause this to occur, and the stop to act improperly, therefore there should be only just freedom before gilding.

The detent should be pivoted without endshake, ratcheting in the steel wheel and just free of the great wheel teeth.

Pivoting.—When the wheels are gilt, the pinion leaves are polished out with a piece of hard wood and red stuff, as the gilding discolours them. The centre wheel, having already the hole in the pillar plate, should have the top pivot made below the top plate and a stopping put into the plate to meet the shoulder; by so doing, a longer pivot is got, and the square for setting the hands can be sunk in the plate. This is more necessary in a keyless watch, the case coming so close to the plate that scarcely any square can be left; in some cases, no square is left, and the piece that carries the cannon pinion has to be pushed out to remove the pinion. If the centre pinion is too long, it occasionally comes in contact with the steel wheel of the fusee; in that case the pinion should be shortened before the top pivot is made.

As the pivot holes in the bar for the third and fourth wheels are generally jewelled, the bar need not be very thick, and should be reduced from the inside to get as much room for the wheels as possible. The fourth wheel pinion must be shortened until the wheel rests on the pillar plate, and the pinions, having previously been polished, may be pivoted: the fourth wheel should have the freedom divided between the plate and the escape wheel, a deep hollow being first cut in the face of the pinion, as the arbor beyond the pinion is so short that without this hollow the pinion would draw the oil from the pivot hole. If there is much freedom in the sink for the third wheel, the back shoulder of the arbor may be left longer, as it is only necessary to keep the third wheel free of the centre wheel. The pivots of the third wheel should be of equal thickness: the seconds pivot of the fourth should be thicker than the top pivot, and if it is made straight, should have the end tapered afterwards, as it is not possible to fit a hand on it otherwise that will not get loose in a very short time. If the holes are jewelled, the pivot shoulders can hardly be made too small; for, although the jewel holes are sometimes sloped off to prevent the adhesion caused by the contact of the flat surfaces, the precaution is of little use if the oil becomes thick, as the oil adheres to the rounded face of the hole much in the same way as if it were flat.

When the fourth pinion is pivoted and ready for running in, the depth with the escape pinion can be got in the depthing tool, and marked on the dial side of the bar; this depth must be taken from

the escape wheel jewel hole with the end-stone off. When the score is made on the bar, the dial should be put on and the seconds hole marked so that the seconds pivot may come in the centre of the hole, or as near to it as possible. Some finishers put in the bottom holes only; but it is not possible to be quite sure of the correctness of a depth until the wheels are run into the frame; therefore a hole should be put in the top plate for the fourth upper pivot, and the depths and the heights be verified.

The third wheel depths are pitched last, that with the fourth pinion being ascertained and marked first, and afterwards that of the third pinion with the centre wheel.

DRAWING FOR ENGINEERS.—IV.

[*Continued from p. 173.*]

INKING IN.

WHEN the student is able to make a fairly neat pencil drawing he should ink in some of the simpler pencil drawings he has done. Figs. 10, 11, 12, and 13, and Example 5 will give preliminary practice in the use of the drawing-pen and ink compasses.

The Indian ink used must be quite black. Most beginners don't rub the stick of ink long enough, and so use the ink too light, making brown lines instead of black on the drawing. The pen must be wiped clean inside and outside before taking a fresh supply of ink. After filling with ink the outside of the pen should be wiped clean. A piece of blotting-paper or a soft rag will serve for this purpose.

Care must be taken to have all the lines on a drawing of the same thickness (except when shade lines are used), and for working drawings they should be rather thick, say from $\frac{2}{100}''$ to $\frac{3}{100}''$ thick. The student must not have the idea, which is widely prevalent, that a mechanical drawing should be inked in with lines as thin as possible.

Circles and arcs of circles must all be inked in before any of the straight lines, since it is much easier to draw a straight line to meet a circle and make a neat joint, than to draw a circle to meet a straight line already inked in. For inking in straight lines it is better to have a ruler a little thicker than would be convenient for pencilling in. By moving the top of the drawing-pen at right angles to the straight-edge, a slight adjustment of the position of the ink line is obtained without altering the position of the straight-edge. By paying attention to this point the joints can be very neatly made.

Neatness of joining lines is of primary importance in inking in. Therefore, if a line has been inadvertently inked in a slight distance from its proper position as given by the pencil line, any other line joined to it must be drawn regardless of the corresponding pencil line. For example, sup-

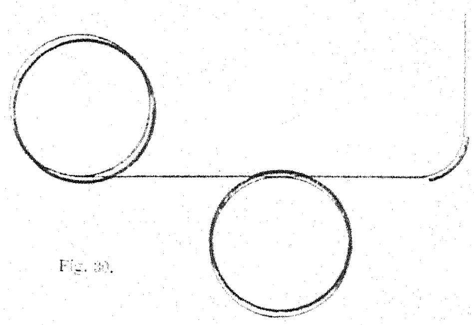


Fig. 30.

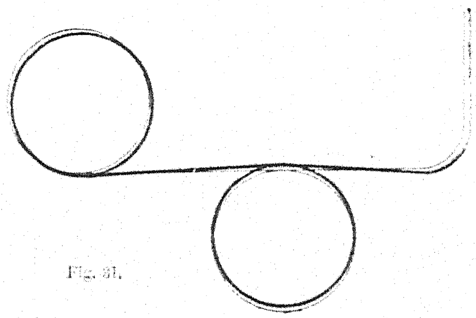


Fig. 31.

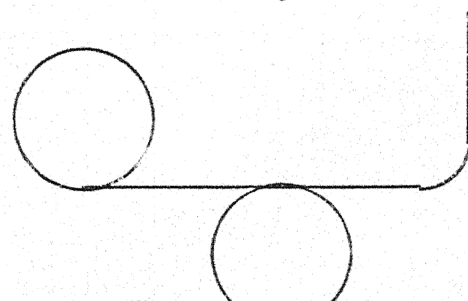


Fig. 32.

pose the thin lines in Fig. 30 to represent a part of the pencil drawing, and in inking in the circles have been drawn in the position shown by the thick lines, the straight lines should be inked in as shown in Fig. 31. The drawing will look much better than if the inking in were completed as in Fig. 32.

When using the pen-compasses the joint will have to be readjusted after any considerable alteration of the radius of the circle to be drawn.

If the drawing is to be "shade-lined" (*see* next lesson) all the lines should be inked in quite thin; the thick lines are drawn last of all, after colouring, shading, dimensioning, etc.

Centre lines are drawn with crimson lake colour; they are drawn continuous—not dotted as in the woodcuts—and may be made a little thinner than the black lines of the drawing.

Dimension lines are drawn with Prussian blue, continuous, and thinner than the other lines of the drawing. There should be a gap left for the figures in the part where it will interfere as little as possible with the rest of the drawing.

Working drawings should have all important dimensions clearly marked in figures. In the best conducted workshops no workman is allowed to put a scale to a drawing for the purpose of scaling off a dimension. The reason is obvious. A tracing after knocking about in the shop for a week or two may have expanded or contracted slightly, and what was originally a length of 12″ may be scaled off $11\frac{3}{4}''$ or $12\frac{1}{4}''$.

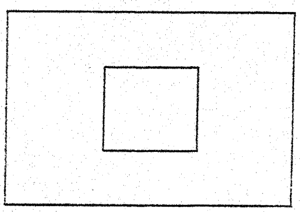


Fig. 33.

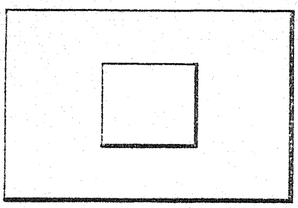


Fig. 34.

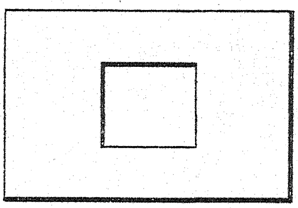


Fig. 35.

The figures and arrow-heads should be in Indian ink. The point of the arrow-head should lie exactly on the line it refers to.

Shade Lines.—The student by this time knows that to represent any solid object at least two projections are necessary. But by suitably shading a single projection we form a much better idea of the form of the object. We will treat of shading in a future lesson. We wish now to show how by thickening some lines of the drawing a single projection gives us more information as to the form of the body.

Fig. 33 is the plan of an object, the outer rectangle being the plan of a rectangular prism. The inner rectangle may represent another prism on the top of the first, or a rectangular hollow on the top surface of the first prism. Suppose now we thicken all lines which cast a shadow: Figs. 34 and 35, although of exactly the same outline, are the plans of two quite different bodies.

The light is usually assumed to come from the top left-hand corner of the paper, so that the bottom and right-hand sides of projecting parts are thickened.

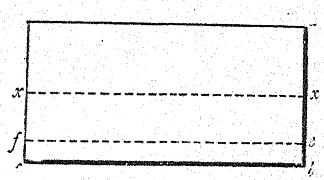


Fig. 36.

Shade lines should only be used on drawings of objects the surfaces of which are nearly all parallel or at right angles to the plane of projection. For example, the plan and elevation of a bevel-wheel should not be shade-lined. Working drawings are not often shade-lined.

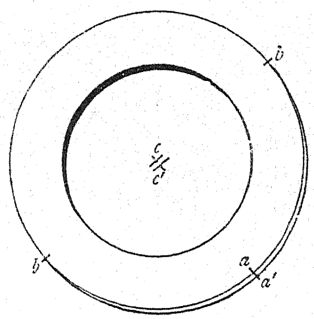


Fig. 37.

Fig. 36 is the plan of a cylinder with its axis $x\,x$ horizontal. The edge represented in plan by the line $a\,b$ casts a shadow and is therefore thickened. The line $b\,c$ is the plan not of a plane surface but of a line on the cylinder at the same level as the axis. The shadow is not cast by this line, but by a line whose plan is $e\,f$. Strictly speaking, therefore, $b\,c$ should not be thickened. In practice, however, since it is the bottom side of the plan, it is made a little thicker than the thin lines of the drawing, but not so thick as the other shade lines.

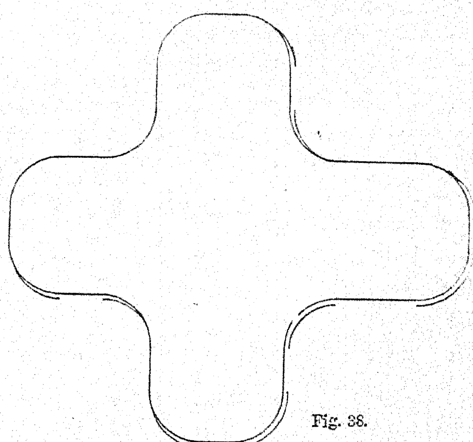


Fig. 38.

Fig. 37 is the plan of a hollow cylinder with its axis vertical. In the outer circle the thickening should be greatest at a and should vanish at b and b. The gradual thinning off of the shade line is accomplished as follows. Set the compasses to the same radius as the original thin circle, the pen

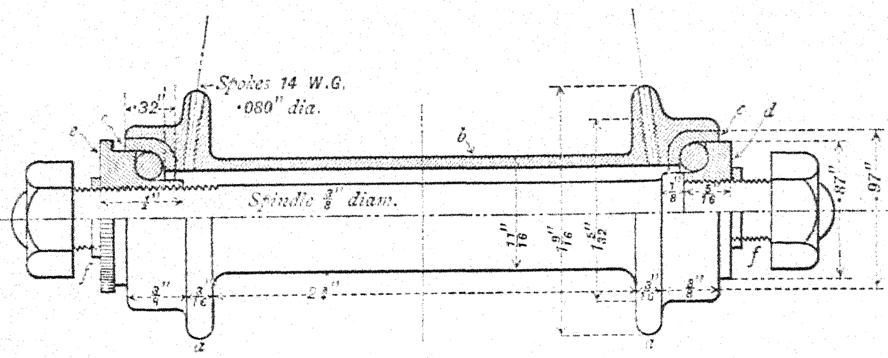


Fig. 39.

being adjusted to draw a thin line, but take a new centre c' in a line through c, making 45° with the horizontal, $c\,c'$ being equal to the maximum thickening required; draw the semicircle $b\ a'\ b$. The space between the two semicircles can be easily filled up by slightly reducing the radius and drawing another arc.

The student should practise shade-lining the cross section shown in Fig. 38, and should be able to do it neatly before attempting to shade-line a more elaborate drawing. The first part of the work of shade-lining is shown in Fig. 38.

The greatest care must be exercised in choosing the lines to be thickened, since a single thick line in the wrong place will quite spoil the appearance of a drawing.

Example 12.—Fig. 39 is a drawing showing a half-section and a half-elevation of a hub and

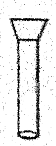


Fig. 40.

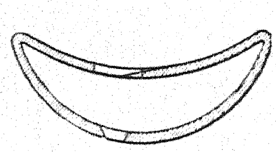


Fig. 41.

spindle for the front wheel of a rear-driving safety bicycle. In this hub the spokes are screwed into the flanges $a\,a$, their other ends having conical heads for attachment to the rim, as shown in Fig. 40. The hub b is made of gun-metal or mild steel, and has a hard steel cup, c, forced in at each end to form the ball race. The spindle is screwed at each end for the reception of the hard steel "cones" d and e on which the balls run. The "cone" d is screwed hard against a shoulder formed on the spindle, and thus becomes practically one piece with the spindle. The "cone" e is adjusted on the spindle until the hub runs freely on the balls, but without any appreciable shake. The spindle is threaded through holes in the fork end, the fork ends occupying the position F. The nuts on the ends of the spindle are then tightened up, the "cone" E being thus locked in position. Fig. 41 is a section of Warwick's hollow rim for a 1¾″ pneumatic tyre.

Draw a section of the hub and spindle twice full size; and a complete side elevation of a wheel 28″ outside diameter, with 32 spokes, and rim and tyre as in Fig. 41, half full size.

DYEING OF TEXTILE FABRICS.—IV.

By J. J. Hummel, F.C.S.,
Professor and Director of the Dyeing Department of the Yorkshire College, Leeds.

[*Continued from p.* 168.]

SILK (*continued*).

As soon as the metamorphosis of the caterpillar (Fig. 11) into the chrysalis state is completed, the cocoons are collected. Those which are intended for breeding purposes are left to themselves in a room heated to 19°—20° C. Three weeks after the spinning of the cocoon, the silk moth, which has now been formed in the interior, emits a peculiar kind of saliva; with this the animal softens one end of the cocoon and pushes its way out. A few days after the females have laid their eggs they die, not being provided with any organ of nutrition. The eggs are slowly dried, and stored in glass bottles in a dry dark place till the following spring.

The good silk is obtained from those cocoons of

which the pupæ are killed by steaming them in a box for about ten minutes.

After killing the cocoons are "sorted," or divided into classes of different quality. In every piece of woven silk the warp threads have to bear the greatest strain, and, as a rule, must appear on the surface of the fabric, hence the best cocoons are chosen for the warp, since they must yield strong, smooth, even, and lustrous fibres. These fibres, too, in the subsequent process of reeling, are manipulated somewhat differently from the weft-fibres. The product of this choice and particular treatment forms the best quality of silk, *i.e.*, warp silk, which is known as *Organzine*. A somewhat inferior class of cocoons is worked up to form weft silk, or *Tram*.

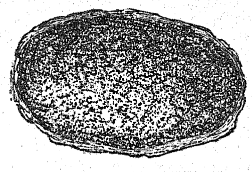


Fig. 11.—Silk Cocoon.

39. *Silk Reeling.*—In the *reeling* process (the machine for which is shown in Fig. 12), a number of cocoons (4—18) are thrown into a basin of warm water A, in order to soften the gummy envelope of the fibres, thus permitting their ready separation from the cocoon. Two threads, composed of an equal number of fibres, are passed separately through two perforated agate guides at B; after being crossed or twisted together at a given point, they are again separated, and passed through a second pair of guides, thence through the distributing guides at D on to the reel E. The object of this temporary twisting or crossing (Fr. *croissage*) is to cause the agglutination of the individual fibres of each thread, and to aid in making the latter smooth and round.

The unequal diameter of each fibre at different portions of its length is taken into account by the reeler when introducing new fibres into the thread to replace those which have run out. The quality of raw silk depends very much indeed upon the care bestowed on the reeling process.

The loss through removal of the external floss (*bourre*) varies from 18 to 30 per cent., according to the cocoons and the care bestowed by the worker.

Reeled Silk, or *Raw Silk*, as it is generally termed, constitutes the raw material of the English silk manufacturer. Before being used for weaving, two or more of the raw silk threads are "thrown" together and slightly twisted by the silk spinner, or "throwster," and in this way the various qualities of Organzine and Tram—also embroidery sewing silks, etc.—are produced.

"Tram" is the product of the union of two or more single untwisted threads, which are then doubled and slightly twisted.

"Organzine" is produced by the union of two or more single threads separately twisted in the same direction, which are doubled and then re-twisted in the opposite direction.

40. *Waste Silk* is that obtained from cocoons in any way soiled or unable to yield a continuous thread.

All such waste silk materials are washed, boiled with soap, and dried. They are afterwards carded and spun like cotton, and yield the so-called *Spun silk*, *Schappe silk*, etc.

41. *Wild Silk.*—Of "wild silks," the most important is the *Tussur* silk (Hindustani, *Tusuru*, a shuttle), also called Tusser, Tasar, Tussore, and

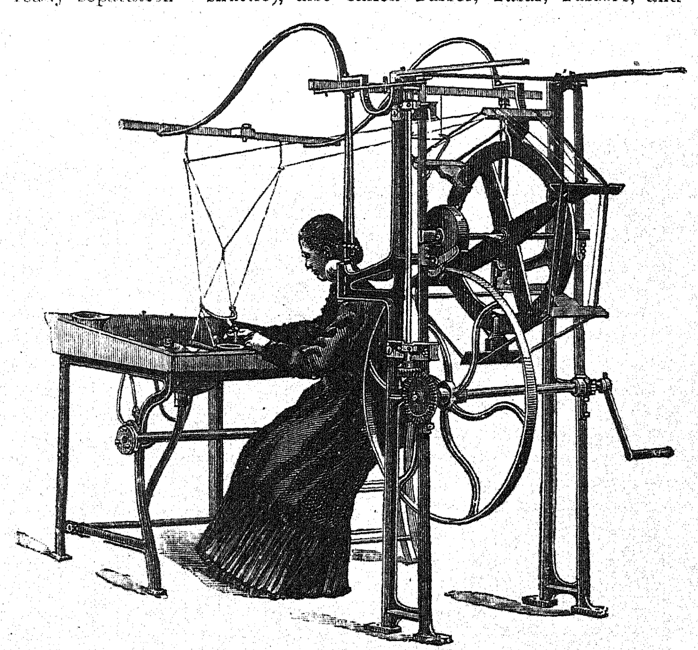


Fig. 12.—Silk-reeling Machine.

Tussah. It is the product of the larva of the moth *Antherœa mylitta*.

The cocoons, which are much larger than those of

Bombyx mori, are egg-shaped and of a silvery drab colour. They are attached to the twigs of the food trees by a stalk having a terminal ring.

Tussur silk is used for the manufacture of the well-known drab or buff-coloured Indian silks. The cocoons are boiled and carded, or even reeled, although this latter process presents difficulties. Silk plush, imitation seal-skin, etc., are largely made from Tussur silk.

Other wild silks are, *Eria silk*, from *Attacus ricini*; *Muga silk*, from *Antheræa assama*; *Atlas silk*, from *Attacus atlas*; *Yama-mai silk*, from the *Antheræa yama-mai* of Japan, etc.

Under the microscope a raw mulberry-silk fibre appears as a double fibre (Fr. *bave*) consisting of

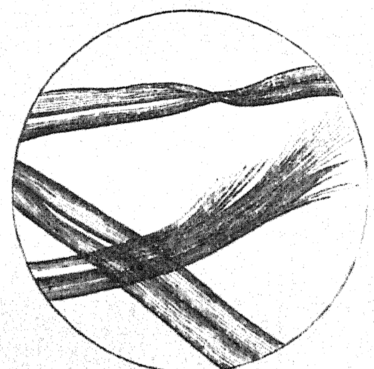


Fig. 13.—Microscopic Appearance of Tussur Silk Fibre.

two solid structureless cylinders (Fr. *brin*), more or less united together; after "boiling off" with soap, however, this double fibre separates into a pair of distinct fibres, having a more or less irregular, somewhat rounded triangular section.

Wild silk is distinguished from mulberry silk by the longitudinal striations seen in each of the double fibres when under microscopic examination (Fig. 13), and by the apparent contraction of the fibre at certain points. The former are due to the fact that the wild silk fibre contains a large number of air channels, while the latter appearance is seen because the more or less flattened fibres are twisted at the contracted points.

42. *Physical Properties.*—The most important physical properties of silk are its lustre, strength, and avidity for moisture.

One other distinctive property which it possesses in certain conditions is that of emitting a peculiar crisp, crunching sound (Fr. *cri*), *e.g.*, when a bundle of silk yarn is tightly twisted and pressed together. This peculiar property is called the "scroop" (Fr. *craquant*) of the silk.

It is absent in raw silk and in "boiled off," or in "souple" silk; it is only manifested if the last bath or solution through which the silk has passed contained an acid salt or free acid. Silk which has been worked in a neutral or alkaline bath—*e.g.*, a soap bath—possesses no "scroop," and feels soft.

In order to develop all the qualities of softness and brilliancy of which silk is capable, it is submitted (while still in the form of yarn-hanks) to the following mechanical operations:—

43. *Shaking Out* (Fr. *secouage*).—The object of this is to open out or beat out the hanks of silk, and to give the latter a uniform appearance by removing all tendency to curl or wrinkle. It consists in hanging the hank of yarn on a strong smooth wooden peg fixed to the wall, and inserting a smooth wooden rod in the loop, which is then vigorously and quickly pulled. The point of suspension is frequently changed, and the shaking out is repeated. The operation may also be done by machine.

44. *Stringing or Glossing* (Fr. *chevillage*).—This operation, which was originally only performed in conjunction with the "shaking out" for the purpose of straightening the threads, and dressing the hanks after diverse operations of the dye-house, has now acquired increased importance, particularly in the case of souples. With these it forms the final operation, the silk being operated upon in the dry state. Its object in this case is to complete the separation of the double silk fibre into its constituent fibres, and to add lustre.

The operation consists in twisting the hanks of silk when perfectly dry. They are hung on pegs, as in the last operation, which it generally succeeds. A stated and progressive tension is thus given, which adds softness and brilliancy to the fibres. This operation can also be performed with the so-called stringing machine.

The stringing machine (Fig. 14) is composed of a series of horizontal pegs A, which can be made to revolve by means of the lever and ratchet L and the cog-wheels K. A second series of horizontal rollers B, situated directly beneath the pegs A, are fixed on elbow-shaped spindles. They are capable of two movements, namely, that of revolving on their own axis—*i.e.*, the horizontal axis of the elbow—as loose pulleys, and also at right angles to this, by the revolution of the vertical spindle of the elbow.

Suppose now the hanks of silk are slung over the pegs A and B; by the action of the ratchet and lever *d* the roller pegs B revolve, and the hanks are twisted, the pegs, weights, etc., being at the same time raised by the shortening of the hanks. Automatically the movement of the lever *d* is reversed, the hanks untwist, and are kept in the stretched

condition by the descending weights. At a given moment, namely, just when the hanks are entirely untwisted, the lever L comes into play, and causes a slight rotation of the pegs A, so that the hanks become suspended in a fresh position, to be again twisted by the action of the lever *d*. The whole of the movements are automatic, and by a few repetitions of this twisting, untwisting, and displacement of the hanks, the operation is complete.

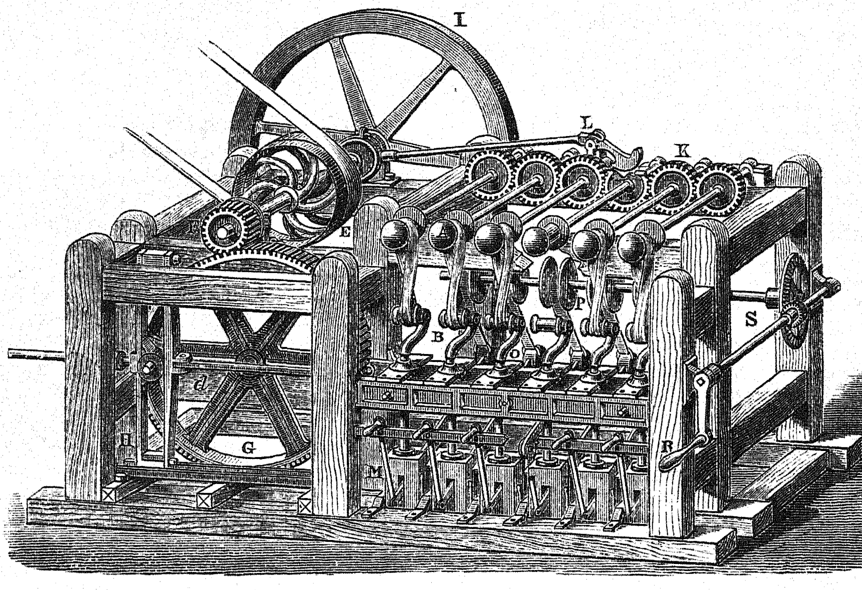


Fig. 14.—Stringing Machine for Silk.

45. *Silk Lustreing.* — This operation, effected by means of the machine represented in Fig. 15, serves to impart the maximum brilliancy to the fibre. It also facilitates the subsequent winding. The dyed and dried, or sometimes incompletely dried, silk is submitted to a gentle stretching between two polished steel rollers, C and D, revolving in the same direction, and enclosed in a cast-iron box, the lid A and side B of which can be rapidly removed when necessary. During the rotation of the cylinders steam is allowed to enter. The stretching is effected by drawing the roller C away from D by means of the hook F, actuated by the cog-wheels at E.

46. *Tenacity and Elasticity of Silk.*—The tenacity and elasticity of silk are remarkably great.

If perfectly dried silk is wetted with water, it contracts about 0·7 per cent., and still more if the water contains mineral or organic substances which are absorbed by the fibre and cause it to swell up. These effects take place during the various operations of dyeing; hence the necessity for stringing, stretching, and lustreing, above alluded to, in order to prevent or counteract the contraction.

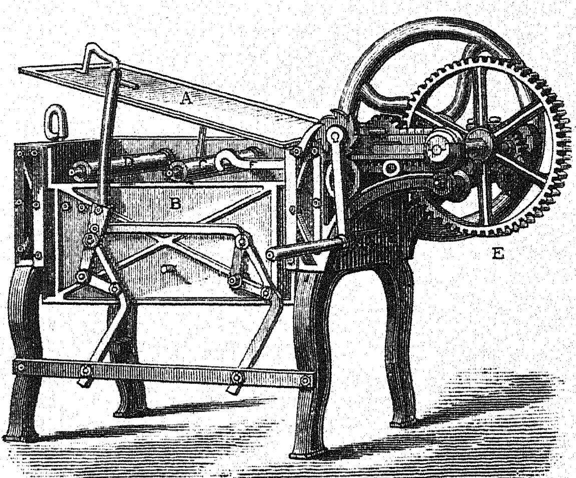


Fig. 15.—Silk-lustreing Machine.

If the fibre is simply coated with such substances as gelatin, albumen, starch, etc., the tenacity will be, as a rule, increased. Some agents, like the simple colouring matters, have no appreciable influence, while others—*e.g.*, astringents, and metallic salts, when used in large excess, gradually destroy the valuable properties of silk entirely.

If silk is heated to 110° C. it loses all its natural moisture, but remains otherwise quite unchanged. Exposed to 170° C., and higher, it soon begins to decompose and carbonise. If a silk fibre be inserted in a flame it gives a bead of carbon like wool, but it does not give off quite such a disagreeable odour.

WOOLLEN AND WORSTED SPINNING.—IV.

BY WALTER S. B. MCLAREN, M.P.

[*Continued from p. 183.*]

WOOL WASHING AND OILING (*continued*).

31. *Recipes for Soap.*—Having obtained good water, suitable soap must be used. Some persons for strong wools use soda alone; but nothing could be worse, as it makes the wool yellow, hard, and brittle. Another method adopted for greasy wool is to steep it in clean warm water, constantly running, for some time before washing it with soap, in order to remove the grease, and so save the soap. This is a mistake; it is well, no doubt, to remove the earthy matter in that or any other way, but this cannot be done without also removing the grease or yolk, which contains so much potash, and which actually helps the soap to wash. The old-fashioned way of washing in the woollen districts was to make a lye or wash of stale urine and alkali. The former was useful, because it contained carbonate of ammonia, and the organic matters were thought serviceable in preventing the alkalies from injuring the wool fibres. This, however, has now gone out of use, and soaps are employed instead. As has already been said, potash, and not soda, should be used for wool-washing. Yolk consists of carbonate of potash to the extent of nearly half its weight, and is the means of keeping the wool soft and silky. Nature in this matter is a sure guide, and experience shows that potash both lubricates and bleaches the wool, while soda has just the opposite effect, making it hard and yellow. Among the chief makers of pure caustic potash are the Green Bank Alkali Company, Limited, of St. Helens, who give the following recipe as the best they know for good soap:—"Take 50 lb. of Green Bank pure caustic potash; put it in any iron or earthenware vessel with 9 gallons (90 lb.) of water. Stir it once or twice; it will dissolve immediately and become quite hot. Let it stand till the lye thus made is cold. Place in any convenient vessel for mixing 20 gallons of cotton-seed oil and 20 lb. of clean melted tallow. Pour the lye into the oil in a small stream, at the same time stirring with a flat wooden stirrer about three inches broad. Continue gently stirring until the lye and oil are thoroughly combined and in appearance like honey. Cover the vessel up, and put it in a warm place for a day. Stir it up again well and leave it for a few days, and the saponification will be complete, and 340 lb. of soap will be the result." This is for a fine scouring soap. If it is wanted stronger, a little pearl-ash can be added, or the oil reduced, say, from 20 to 18 gallons. For very greasy wool it should be stronger still. This is the cold-water process, no boiling being needed. If boiled, the soap is made more quickly, the method recommended being to take 18 gallons of oil and 18 lb. of tallow: boil them with 21 gallons of caustic potash lye of 18° Baume. Then add 7½ gallons more lye of double the strength, and about 6 lb. of pearl-ash, to prevent stringiness; continue boiling, and the soap will almost immediately be made. Borax is a good substance to use, as are also carbonate of ammonia and caustic ammonia. In every case let the soap be of good quality, for nothing is worse than by using a cheap strong soap to lose infinitely more in the wool than the soap costs.

32. *Danger of Strong Soap and Hot Water.*—An indefinite number of recipes could be given for soap equally simple with these, but they are not necessary. The chief point to be observed is that for finishing and sizing goods or yarn a neutral soap should be used—that is, one in which the alkali and oil balance each other; but for wool-washing there should be a slight excess of alkali, depending on the grease and dirt in the wool; but, above all things, there should not be too much, or the wool will be burnt. There should only be enough free alkali to remove the grease and dirt from the surface of the wool. If there be more than this, the fibre of the wool itself is instantly attacked, and its nature is destroyed. Nor should the water be too hot. Any heat which the hand cannot bear is too great, but dirty wool naturally requires more heat than clean, and therefore no exact degree can be given, but it should not exceed 100° F. in any case. It is so easy to make soap, and the risk in buying it is so great, that it is surprising that all manufacturers do not make it for themselves. It is a usual and desirable thing, when the wool goes through three or four washing bowls, to put a stronger soap in the first than in the others, in order to extract at once the dirt and

grease. In the last bowl, on the other hand, a soap is used in which the oil is in excess of the alkali, so that the wool is fed and softened before it is dried. When it is remembered that the little cells which compose the fibres of wool are swollen and raised by the heat of the water, and the wool itself actually softened, it is easy to see that a good oily soap will be able to penetrate the fibre, and, by depositing some of the oil upon it, will makė it softer to work in the future processes. But it is better to take care that the natural fats have never been taken out, as no oil can adequately replace them. Some persons also finish with putting the wool through a bowl of clean water, but though this may improve the colour, it prevents any oil from being left in the fibre, and this is not always desirable. It is a fact not generally appreciated by wool-washers that wool can be dissolved altogether till nothing is left visible. Hot water alone will not do this—wool may be boiled without being dissolved—but put a little caustic potash, or anything of a similar nature, into the water, even if it be very far from boiling, and the wool will rapidly disappear; the hotter the water the quicker it will melt. This shows the danger of having too strong a soap, and also too hot water, for even if every fibre merely lose the smallest fraction of its surface, the total loss is great. And besides, it will be the serrated points which will go first, and thus the spinning properties will be spoilt. Very hot water alone, even without any soap, spoils the wool, by taking out its natural curl, and thus destroying its spinning power, and many a bad spin is due to nothing more than the excessive heat of the sud in which the wool has been washed. No one can estimate the amount of loss caused by these two evils—too strong soap and too hot water; and they should be carefully watched by the person in charge.

For washing mohair some persons use only cold water, thinking it better not even to wash the fibres thoroughly. They cannot stand as much washing as wool certainly, nor can alpaca, but the experience of the trade generally does not favour cold-water washing, but rather a moderately good washing in a sud not too warm, with a neutral soap, and not too much of it. No lustre wool should be washed in really hot water, for it must be remembered that lustre is due to the reflecting power of the hard horny surface of each of the tiny scales which go to make up the fibre. Hot water, by partially softening the surface, removes the polish, and nothing can restore it. The glaze disappears, and the wool becomes dull. If there is alkali in the water, the damage is done all the more quickly, and therefore the soap should be perfectly neutral. Water between 60° and 70° F. will generally be found hot enough.

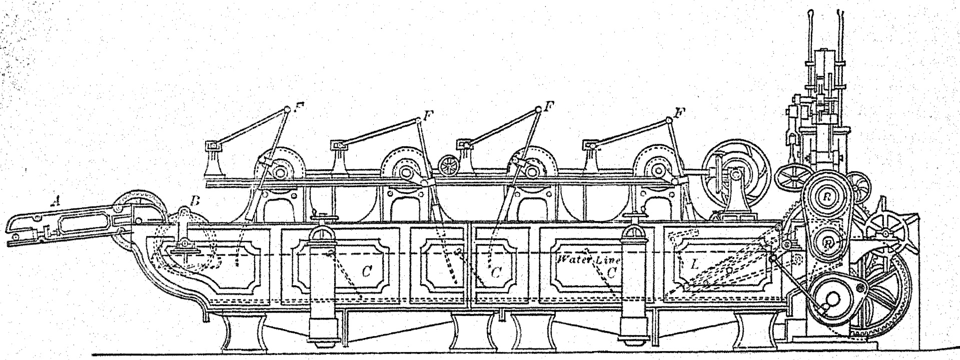


Fig. 4.

33. *The Washing-bowl.*—A short description of the washing-bowl, and of the principles on which it works, is now necessary. Formerly all washing was done by hand. The bowl was filled with the sud, and the wool put into it, while one or two men with wooden poles stirred it about, and finally lifted it on to a travelling apron which carried it between a pair of rollers, by which the water was squeezed out. The same principle still prevails, but machinery does the work. In Fig. 4 is represented one of the best forms of washing-bowl, made by Mr. John Petrie, of Rochdale. The wool is placed on a "feeding-apron," A, and carried down into the water by a brass roller, B; four forks, F F, gradually carry the wool forward through the sud, and through three stationary forks, C, which are fixed in the water. It then arrives at a lifter, L, which raises it from the water to the rollers, R R, which squeeze the water out, and as

soon as it has passed through them it is shaken and opened by a wooden roller made like a fan, and then thrown on to the floor. The action of the lifter L is the chief peculiarity of this bowl; it is the entire width of the bowl, and is made by placing side by side a number of bars of wood. Into these bars spikes are inserted, sloping upwards, and towards the rollers. These bars have a short stroke motion; every alternate one moves up a few inches, while the other set of alternate ones move down; at the next stroke those which moved down now move up, and those which moved up now move down, and so on, turn about. By this motion the wool on them is gradually carried up to the rollers, and so out of the bowl. As each set of bars moves down, the wool on them is caught by the set that moves up, and at each stroke is thus raised about 3 inches till it reaches the rollers. As the wool is floated gently on to the bottom of the lifter in the water, it never goes up in lumps, and thus passes evenly through the rollers.

34. *McNaught's and Jefferson's Bowls.*—This improvement has been effected in consequence of a change in the idea of washing wool. It was thought a good thing to swill the wool well, to rinse it out by quick stirring, and finally to give it one rather rapid passage through the sud by means of a fork which lifted it entirely out of the water, high up, on to an apron, which took it to the rollers. It is now seen that this is a mistake. If wool is drawn rapidly through the water it clogs together and becomes stringy, and in doing so binds in all the dirt that may be attached to it. But if the wool floats gently on the water, its natural tendency is to spread out very openly, and thus make all the dirt and foreign matter separate from it and sink. Hence it is seen that the forks of the bowl must move very slowly indeed, so as to give the wool rather the appearance of floating quietly on a slow current, rather than that of being dragged through the water by rods. An exceedingly good machine has been made by Messrs. J. and W. McNaught, of Rochdale, to accomplish this. Instead of the forks moving one after the other through the water and thus swilling the wool, they have fixed all their forks to an iron frame which hangs by chains entirely above the bowl. By means of an eccentric wheel it drops down to the level of the water, moves very slowly along with the forks in the water, which gradually propel the wool in the gentlest way, and then it is lifted up again, moved backwards to its starting-point, and again descends. In this bowl, too, the rollers are at the water's edge, so that the wool does not need to be raised out of it. But this principle is carried out with greatest success by Messrs. Jefferson Brothers, whose squeezing rollers are illustrated in Fig. 5.

The lowest rollers, C C, have their nip below the level of the suds, D. The wool, therefore, which floats up to it, and is also pushed forward by the fork A, is caught by the nip while still loose and floating freely in the water, and before it has any opportunity of becoming compact and stringy. As soon as it passes through the nip of C C, it comes again into the sud, and is quite saturated before reaching the second nip E C, which squeezes it a second time and passes it on to the third rollers, E F, for a final wringing, and so on along the apron G into a box ready to receive it. The top roller, F,

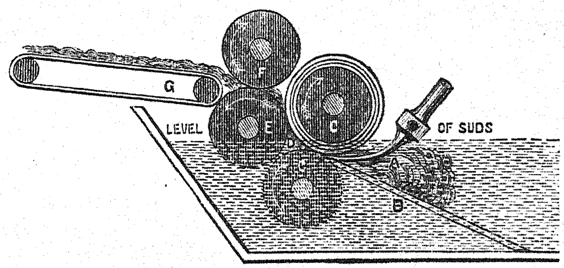


Fig. 5.

is often made as a beater or fan to shake the wool instead of squeezing it, and so make it lie lighter and looser on the drier. This is found to be an improvement. This method avoids many difficulties which the washer of long wool encounters with other machines, such as the wool forming into lumps and choking the rollers, or falling back off the apron into the sud. It undoubtedly enables the wool to be squeezed more evenly, and while more spread out; a much better colour is also obtained, with a great saving of soap. The latest improvement however, is to do away with forks altogether, and simply float the wool through the bowl. Several machines for this purpose may be mentioned, notably, those of Mr. John Petrie, Jun., Ld.; Messrs. Taylor, Wordsworth, and Co.; Mr. John Perry's. It is not necessary to describe these in detail, but the principle consists in having two bowls in each machine, one above the other. The upper one is for washing the wool, the under one for holding the surplus washing liquor. As the wool is fed into the upper bowl, a pump raises the liquor from the lower one, and drenches the wool with a strong jet. The liquor then flows along the bowl, the pumping going on constantly, and carries the wool with it. The bowl has a perforated false bottom, through which the solid particles of dirt fall. To prevent the wool travelling too fast along

the bowl, various mechanical contrivances are adopted to retard its progress—the one used by Mr. Petrie being the alternate lowering and raising of two wooden lattices, or grids, turn about, which, when they are down, retard the progress of the wool. In Messrs. Taylor Wordsworth and Co's bowl the process is further assisted by what are called passers or shower-boxes, underneath which the wool passes. These have perforated bottoms, and the sud, as it is pumped in, passes quickly up and down through the holes, and thus also through the wool. It is the passage of the sud through the wool, instead of the wool through the sud, which is the great improvement in these bowls. The wool gradually passes along till it reaches the delivery rollers at the other end, which squeeze all the water out. A great advantage is also found in passing the wool forward to the squeezing rollers while full of sud, for, as stated above, a better colour is thereby obtained. The liquor itself flows back into the lower bowl, and is again pumped up to do its work afresh. The great advantage of this system is that the wool is never stirred about or matted. The locks lie relatively to each other almost in the same position as when they enter the bowl, and instead of being forced through the water, the water is forced through them. As the rate at which the wool travels can be reduced at pleasure, while the constant stream of water is maintained, the quantity of water or liquor which comes in contact with the wool, and flows through it, is far greater than can possibly be the case in a fork machine; and it really resembles washing the wool in a stream of water. By this means the wool is delivered in a perfectly open condition; and just in proportion as matting is avoided, the quantity of noil, or short wool, in the combing process, is reduced.

35. *Dr. Braun's Machine.*—There is another method of wool-washing—invented by Dr. Braun, a German, and tried in Verviers—which has probably not been tried in England, but which is here given on account of the remarkable results which are said to have attended it. Though the process itself is evidently complicated and clumsy, it is worth the attention of wool-washers who may be able to bring it into practical use. The description is quoted from the *Textile Manufacturer*:—

"This apparatus is designed for a new method of cleansing wool, consisting in washing the raw material first with water, then with alcohol and ether, and again with water. By the use of the apparatus the proceeds of the washing are not lost, but can easily be recovered and utilised, while the alcohol and ether are used continuously and with but little diminution. The apparatus (Fig. 6) consists of a vessel, A, by preference made cylindrical, containing a well-closing lid; above this vessel are three other vessels, B, C, D, situated at a higher level; and on the same level as A is a distilling vessel, E, with cooling-pipes situated above the receptacles B, C, D. The different vessels are connected by pipes, in the manner shown, and the process is carried out in the following way, viz.: B is filled with water, C with alcohol (of 60 per cent.), D with ether, whilst A contains the wool to be cleaned, which latter is compressed between two frames containing sieves or perforated plates; all cocks having been closed, those marked 7, 1, 6 are opened first; thus the water passes from B into A from below, and expels the air from between the wool. As soon as the water passes out of the cock 6, the

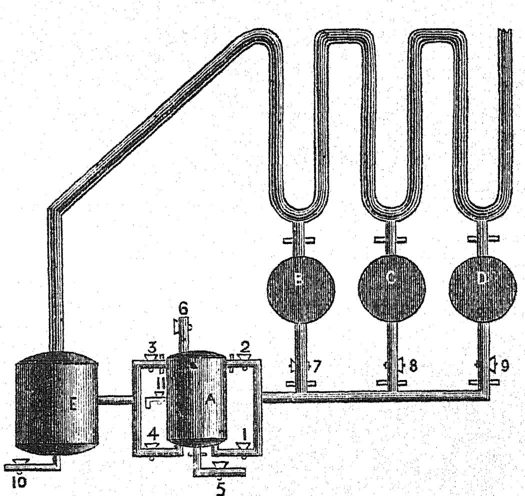


Fig. 6.

two cocks 6 and 1 are closed, and 2 and 5 opened, until the water passing out of 5 is quite clean; cock 7 is then closed, to stop the flow of the water, and 8 opened to admit alcohol, until cock 11 shows alcohol; cocks 8 and 5 are then closed to stop the flow of alcohol, and 4 and 9 opened, cock 2 being still open, which admits ether; the latter then, with the assistance of the alcohol, drives out the water which is still in the lower portion of the wool, and into the vessel, E. When the first portions of ether have expelled the alcohol, the remaining portion will commence to dissolve the grease in the wool, and carry it into E. As soon as the fat has been removed, the cocks 4, 2, and 9 are closed, and 8, 1, and 3 opened, until the cock 11 shows alcohol; cock 8 is then closed, and 7 opened, which causes the alcohol which is in the lower part of the wool to carry any remaining ether into the

vessel E. As soon as all ether and alcohol are removed from A, the cocks 7, 1, and 3 are closed, and 6 opened. The wool, now free from grease, alcohol, and ether, is taken out of the vessel A, and washed with tepid water, while A can be filled with a fresh portion of material to be operated upon. The vessel E now contains water, alcohol, ether, and fat, which substances may be distilled in different ways. The fat and the greater portion of the water are drawn off by means of the cock 10; the distilled ether collects in D, the alcohol in C. and a part of the water in B; the alcohol and ether are almost completely recovered; the loss of water is easily replaced. The arrangement may be varied by having several vessels E, and using each of them for a separate liquid. The inventor claims greater efficiency than by the usual mode of washing, and maintains that the wool is preserved in a better condition, which latter assertion seems to have been borne out by some experiments made at Verviers, in Belgium. A quantity of Buenos Ayres wool having been divided into two portions, A and B, A was washed by the above-described process, and B in the usual manner. The results were the following. viz.: A was whiter than B; A lost in burring 6 per cent., while B lost 13 per cent; in spinning A, 41 out of 1,440 ends broke, while in spinning B, 100 broke out of the same number; out of A 22,000 yards were spun, but out of B only 20,000; the yarn spun out of A is softer, more elastic, more regular, stronger, and more even in colour after dyeing, and winds very much easier. If the method we have described has all the advantages which are claimed for it, it proves again that scientific treatment is superior to the old way of working by rule of thumb."

CARPENTRY AND JOINERY.—IV.

By B. A. Baxter.

[*Continued from p. 175.*]

SIMPLE CONSTRUCTIONS.

Herringbone Strut.—Before the floors are laid it may be well to describe the herringbone strut. This a double row of pieces of stuff nailed diagonally between the joists from the lower to the upper edges, as drawn in Fig. 31. The thickness of these pieces is immaterial, about $1\frac{1}{2}$ inch square or 2 inch by $1\frac{1}{2}$ inch will do very well. The ends of the struts are, of course, cut to an angle to fit the joists, and as any slight difference of distance between the joists will alter the length and angle, I shall shew an easy way to mark the angles. Draw across the joists two lines parallel to each other and at a distance equal to the width of the joist. Then by applying the stuff for strut to the marked joists, the length and angle of ends can be marked on strut from below, and the same for each pair of struts (Fig. 33). They will of course, be

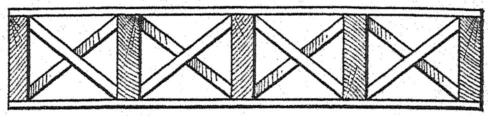


Fig. 31.

nailed to the joists and will stiffen them, and reduce the liability to vibration. Such a row of struts ought to be inserted about every six feet. It ought to be remembered that short joists are stronger than long ones of the same section, so that unless the joists are supported by the partitions, joists from

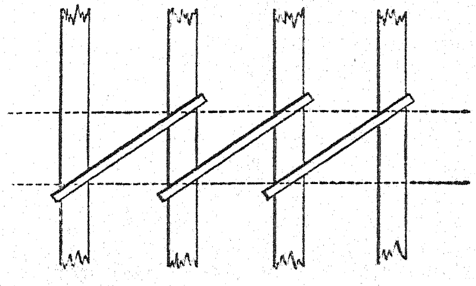


Fig. 32.

front to back of an ordinary house would require not only longer lengths but larger scantling.

Flooring.—In laying flooring the young carpenter should endeavour to obtain dry flooring, and it is useless to expect much drying when laid (as is often done) upside down on the joists in a newly erected building.

The form of cramping the boards together, known as "folding," must be mentioned and condemned.

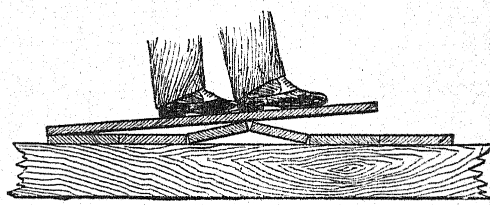


Fig. 33.

It consists of laying and nailing a first and sixth board about a quarter of an inch nearer each other than the combined width of the inner four boards, the next to each being placed, while the two inner boards are made to meet each other as in Fig. 33, and are then squeezed down by jumping on a board placed above them. This is certainly an effective way of getting floorings close, but it should never

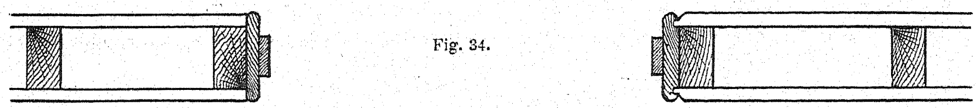


Fig. 34.

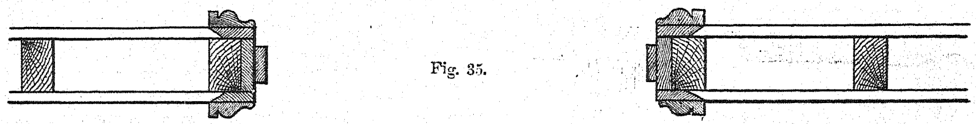


Fig. 35.

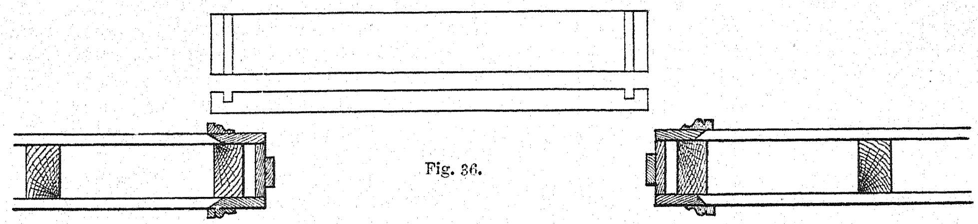


Fig. 36.

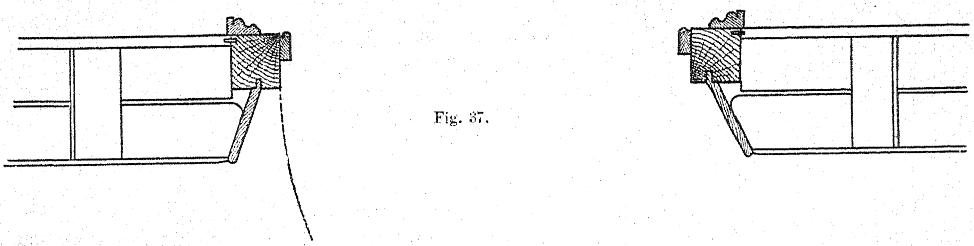


Fig. 37.

be resorted to on upper floors, a pair of proper flooring cramps being superior and safer.

Door Frames and window frames next deserve our attention. Door frames, when occurring in partitions, are formed by the proper disposition of the ordinary timbers composing the partition, allowing space for a lining to form the visible frame; this lining ought to be in, or nearly in, contact with the frame proper, or the weight and the slamming of the door will soon tell tales (Figs. 34, 35, 36). In outer walls or brick partitions the frames are a separate construction (Figs. 37 and 38). The frames are usually made of a lintel, longer than the width of the frame, into which the uprights are tenoned. Sometimes the lintel is cut in the form of a bridle, which may assist in the fixing by allowing a key in building in. Many door frames have a stone sill, in that case the stone is mortised for the tenons at bottom of the styles, and in all cases where there is a probability of damp the mortises might be cut through with advantage. In the case of outer door frames the joiner will be called upon to prepare the frames, as a more finished appearance is demanded.

Window Frames form also a link between carpentry and joinery. They are of two sorts; those for casements are almost identical in construction with door frames, except that precaution is taken to exclude draught and rain (Fig. 39 and 39A), but for sashes the frames are of a special construction, which may be described—first, the sill (or cill); this is generally of oak, and may be bought in suitable sizes for either $1\frac{1}{2}$-inch or 2-inch sashes. The section of a sash frame sill is like Fig. 40, in which the bead is fixed on the flat surface and the lower sash on the slope next, the lower sinking being rebated so that water will not drive between the sash and the sill. The pulley styles are next in importance: they are prepared to a width which is governed by the thickness of the sashes and the parting-bead. The groove for the parting-bead must be made the thickness of one sash from the edge; of course the groove must be just wide enough to hold the parting-bead. If machine-made parting-beads are used, see that a plough-iron is in hand to suit: beyond the plough groove will be the space for lower sash, but in order to cover the joint, the bead is usually wide enough to exceed the thickness of the lining by about $\frac{1}{8}$ of an inch, so that the width of the pulley styles will be for 2-inch sashes (2-inch nominal)—sash $1\frac{7}{8}$, groove $\frac{3}{8}$ sash 2 inches, of which the bead covers $\frac{1}{8}$ (Figs

40, 41, and 42). The length of the frames being fixed, the styles may be set out; they are generally

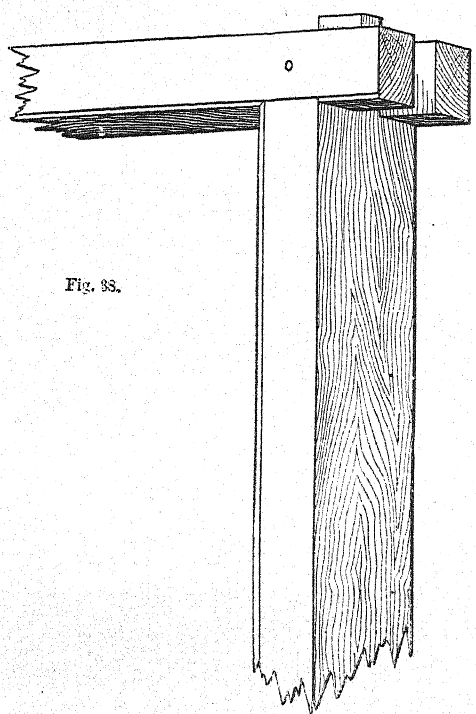


Fig. 38.

housed into the top and nailed, the sill being generally wedged as shown (Fig. 42 and 43).

Note that the sill is equal to the total thickness of exceed the width of sill. The thickness of these linings therefore may be varied, but should not be less than $\frac{3}{4}$ inch.

Cutting Deals.—Here it must be explained that in cutting deals for the purposes of the carpenter and joiner, the sawing wastes some wood, and therefore leaves the boards from $\frac{1}{12}$ to $\frac{1}{8}$ of an inch thinner than the nominal thickness. Hence when the deal (9-inch by 3-inch) is cut once into two boards, it is almost always cut on a circular saw bench, and the thickness of the saw, rather more than $\frac{1}{8}$ of an inch, taken from the 3-inch deal, leaves each board rather more than $1\frac{3}{8}$ inch, although such a board is called $1\frac{1}{2}$-inch stuff. Similarly, so-called 1-inch boards are rarely more than $\frac{7}{8}$, being $\frac{1}{3}$ of the 3-inch deal reduced by the two necessary saw cuts.

Sometimes two cuts are made with a circular saw, but usually two cuts and upwards are made by a deal frame, which is a machine using reciprocating saws, which being strained tightly are capable of being made thinner, and vibrate less, than a circular saw. The carpenter and joiner is very dependent upon the quality of the sawing, and badly sawn stuff is not now common, owing to improved machinery and skilful saw-sharpening.

When deals and planks are cut into boards, the cuts are called "deep cuts"; when cut into squares or strips by cutting parallel to edge instead of the larger surfaces, the cuts are called "flat cuts." Flat cuts are made on the circular saw bench, and in the absence of special instructions the machine sawyer divides the deal or plank into equal parts, thus 9-inch by 3-inch with two *flat* cuts means three pieces 3 × 3, the same with two *deep* cuts

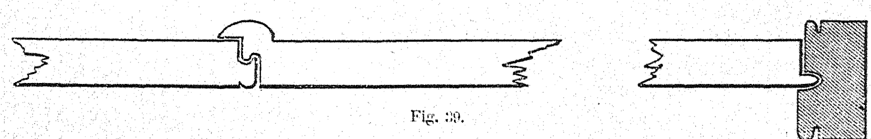


Fig. 39.

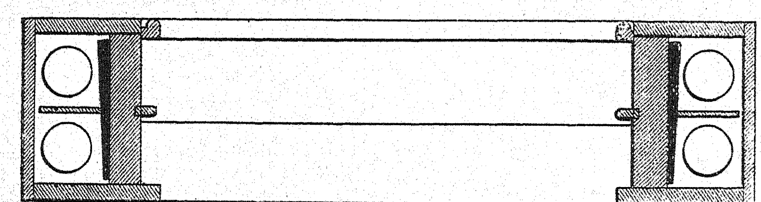
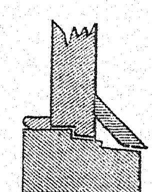


Fig. 43.



Casement Frames

Fig. 39A.

the frame, so that if the sashes are of known thickness the pulley styles must agree as just stated, and the linings must be of a thickness which when added to the width of pulley styles will not

means three boards 9-inch × 1-inch. While if $1\frac{1}{4}$-inch boards are wanted, they must be ordered two deep cuts $1\frac{1}{4}$ inch. Battens vary so much, and are so frequently used uncut for basement

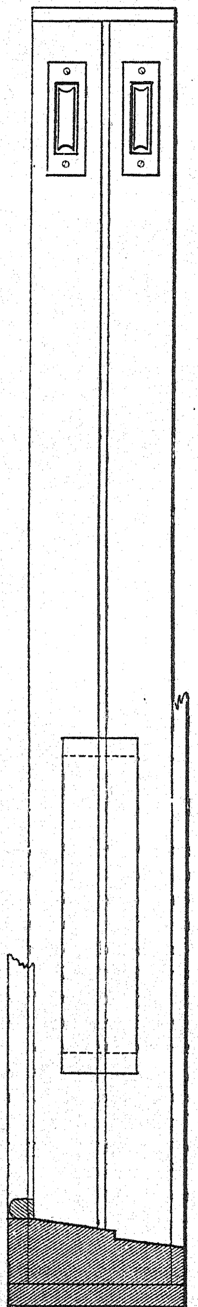


Fig. 40.

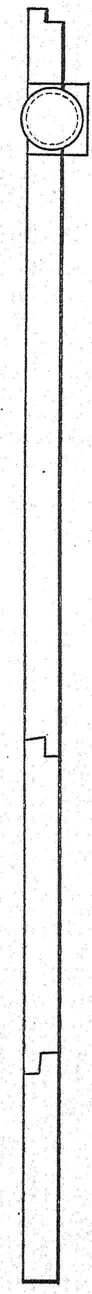


Fig. 41.

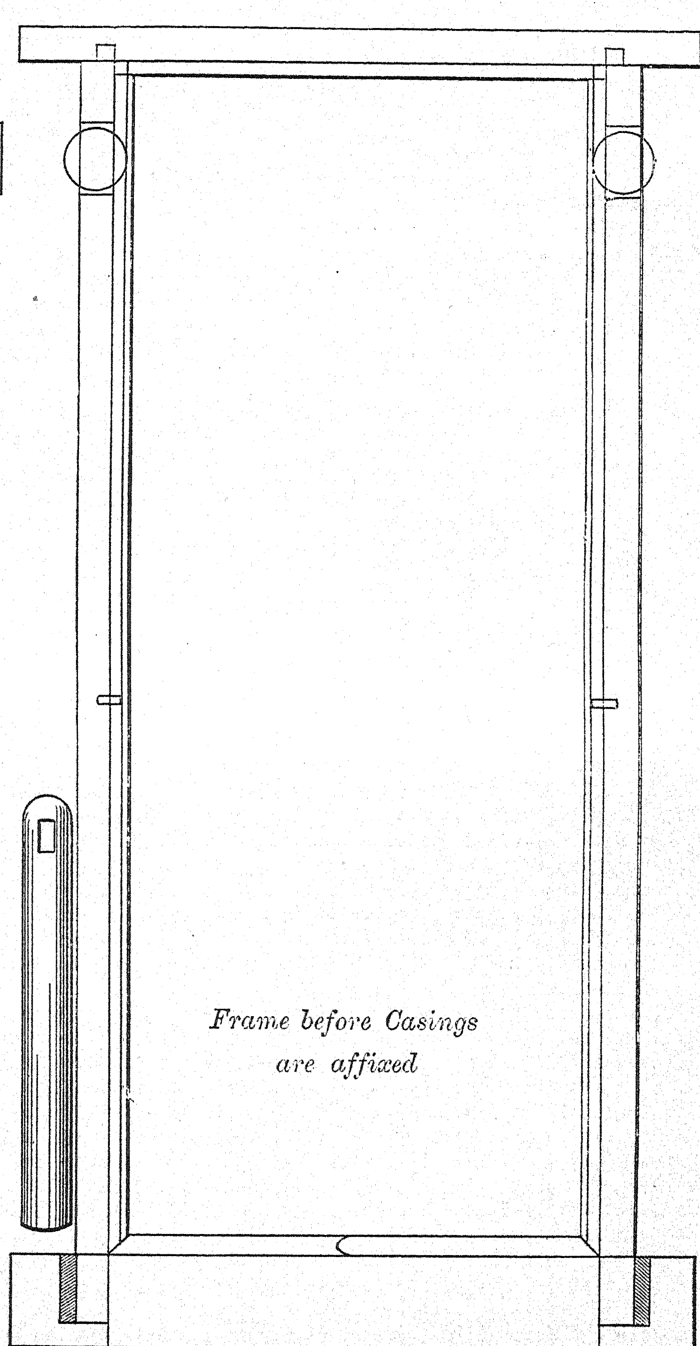
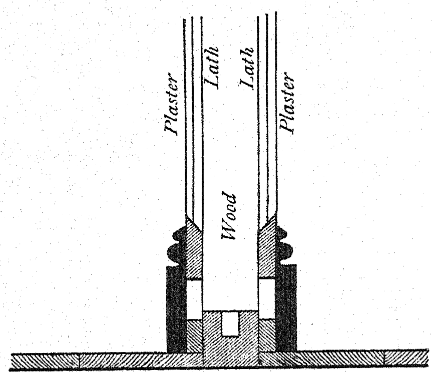


Fig. 42.

joists, sleepers, etc., that if cut, orders nearly always need to be special according to size of wood required.

PARTITIONS.

Partitions are for dividing a building into separate rooms or compartments where walls are not required. As frequently the upper floors of a building are more subdivided than the ground floor, partitions are often required where there would be no sufficient support for the weight of brickwork.



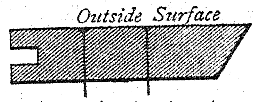
Section of Partition showing Grounds and Skirting.

Fig. 44

In such cases, as it is possible, the partitions should also help to support the floor or ceiling above. When the joists cross the partitions at right angles, this will be easy. The surfaces of partitions are generally covered with laths and plastered, though sometimes match-lining is used. Matched boarding has the advantage where quick and cleanly alterations to business premises are required, but is apt to conduct sound too freely to be used in dividing rooms from each other.

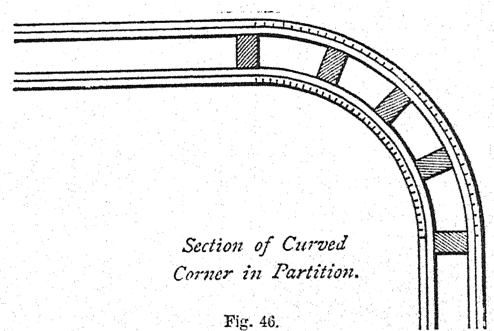
The construction consists of top and bottom rails mortised for the reception of the uprights, which, with the exception of the door openings, should be not more than 12 inches apart. The tenons on the uprights need not go through, though very little time can be saved by mortising half-way through the top and bottom rails; spacing pieces ought to be inserted here and there wherever any possibility exists of the uprights bending. The oblique rails shown in Figs. 17 to 20 are of course for the purpose of keeping the whole square, and therefore ought to be in one piece; the uprights may be halved to them, or cut to the proper angle and nailed. The timber used may be $4\frac{1}{2}$ inches wide by 2 or 3 inches thick. Openings for doorways will be made by spacing out the uprights so that two of them are placed at the proper distance for the lining which constitutes the visible door-frame. The oblique struts must also be so arranged as to avoid door openings.

The lower portion of the partition is finished with a skirting. In order to fix skirtings at the proper distance from the face of the timbers, skirting grounds are fixed before the plastering is applied. This will be seen in Figs. 44 and 45. In 44 a section of partition shows the grounds, retaining the plaster in its proper position and available for fixing skirting. Pieces of wood of equal thickness to the grounds may be fixed to each upright. Fig. 45 shows an alternative treatment of the edges of the ground, which may be either grooved or cut at an angle.



Alternative treatment for Grounds

Fig. 45.



Section of Curved Corner in Partition.

Fig. 46.

Sometimes partitions present an external angle, in which case the carpenter will probably be called upon to fix grounds forming the angle, for wood bears blows better than plaster, the wood being grooved or cut back, as just explained, to form a key for the plaster. Often the angle is avoided and the partition curved on plan, fixing the uprights in suitable places, and bending the laths round the curve. The skirting, however, must be cut out of the solid or joined in pieces, or else the concave side is sawn almost through at intervals and bent and nailed to the uprights (Fig. 46).

Sometimes in a ground floor partition the spaces between the timbers are filled with bricks. This must not be done unless the weight has been provided for; if the partition stands over a brick wall it will be well supported.

Casement, sash, and door frames must have the same provision for keying the plaster as here described for partitions, either by grounds fixed or suitable treatment of their edges.

PRACTICAL MECHANICS.—IV.

By R. Gordon Blaine, M.E.

Assoc. M. Inst. C. E., &c.; Senior Demonstrator and Lecturer on Mechanical Engineering and Applied Mechanics at the City and Guilds of London Technical College, Finsbury.

[*Continued from p.* 188.]

MECHANICAL ADVANTAGE AND EFFICIENCY—PRACTICAL TESTS—ARRANGEMENT OF RESULTS—LAWS AND DEDUCTIONS.

In Fig. 25 a screw-jack is shown arranged for an experiment, and here two equal, opposite, and parallel forces (which form what is known as a *couple*) act on the screw; this arrangement en-

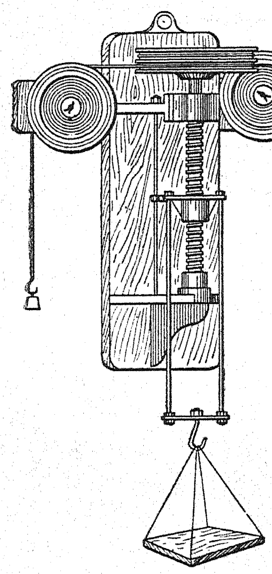


Fig. 25.

suring a *turning* motion only. If when *one* force is applied to turn the screw, it tends to push the screw over against its bearings, and extra friction is thereby introduced. The load on this experimental jack is raised in the scale-pan, as shown in the figure.

Often, in order to attain a still higher velocity-ratio, and hence raise a greater load by the application of a given force, a worm and worm-wheel are introduced between the handle and the screw, as shown in Fig. 26.

The velocity-ratio, as found by the method already considered, would in this case have to be multiplied by the velocity ratio of the worm and worm-wheel, which is T to 1 if there are T teeth in the wheel. The arrangement will be understood from a study of the views shown in Fig. 26.

The handle H H is attached to a screw or worm S S, which works into teeth formed on the outside of the nut N. The main screw M is prevented from turning when the handle is rotated, hence the nut N rotates about the screw M. But the nut N is also

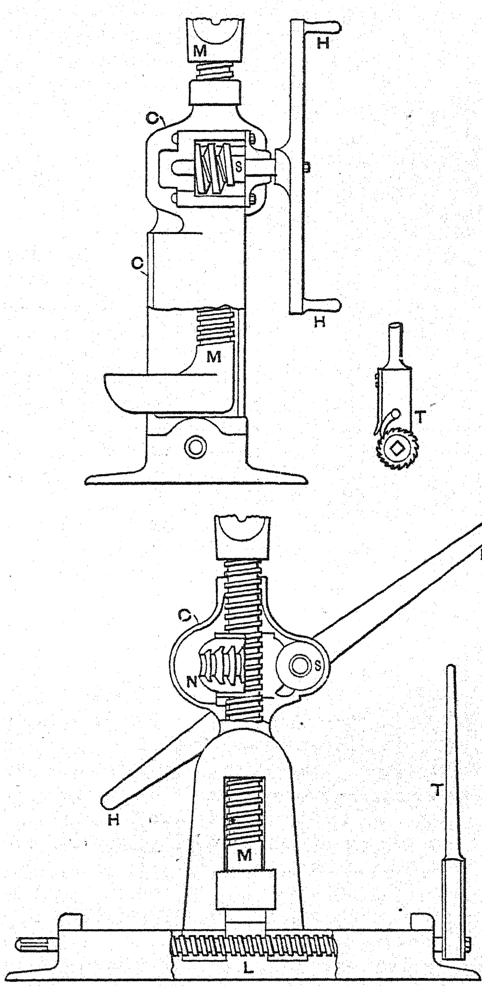


Fig. 26.

prevented by projections on the casing C from moving bodily in the direction of the axis of M, hence, since there must be a *relative* motion equal to the pitch for every turn of the nut relative to the screw, it is evident that since the nut cannot advance or recede, the screw must do so, and hence a load resting on the screw M is raised or lowered. With the ordinary jack, as shown in Fig. 24, when the handle is rotated once, the screw advances a distance equal to the pitch, but here if there are, say, twenty teeth on the nut N, which

we may call the worm-wheel, the handle H must go twenty times round before the nut is moved once relative to the screw, and hence the ordinary velocity ratio has to be multiplied in this case by 20. It is evident that the arrangement gives a means of raising at a *very slow rate* a large load by the application of a comparatively small force. The *efficiency* of the arrangement, however, is probably not great, owing to the considerable amount of friction introduced. The method of moving the jack laterally so as to get it under a waggon, or other load, is shown by the screw L and the ratchet and handle T.

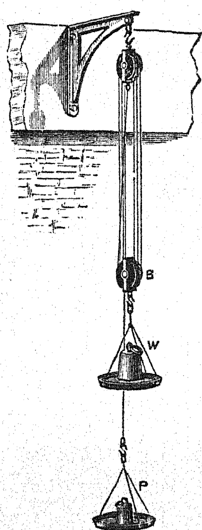


Fig. 27.

When the nut is solid, we know how to find the relative motion of nut and screw, but if the nut be fluid, as in the case of the screw-propeller of steamships, there is "slip," and the relative motion is *less* than that which the rule gives by a fraction which represents the "slip."

PULLEY BLOCKS.

The arrangement of pulley blocks shown in Fig. 27 is probably familiar to the reader. Here there are six parallel cords, and if the lower block is raised *one* foot, each of the six cords is slackened one foot, hence *six* feet of cord pass over towards P, hence the velocity-ratio is 6 to 1. It will be found in general that the velocity-ratio or *hypothetical mechanical advantage* of such an arrangement is *twice the number of movable pulleys;* the movable pulleys or sheaves being those which rise or fall as the load moves.

Thus in this figure the sheaves of the lower block may be regarded as *movable* whilst those of the upper block are *fixed.* If we pass a cord over a *fixed* pulley and raise a weight by it we gain *no* advantage as regards force, and the velocity-ratio is simply 1 to 1. But if, on the other hand, we use a movable pulley, as in Fig. 28, it is apparent, on a little consideration, that the hand D must move twice as far as the load W. This arises from the fact that at any instant a point on the pulley where the cord leaves it at the side nearest E, is motionless just for an instant, all points of the pulley moving about the motionless point as centre at that instant. This point is called the *instantaneous centre of motion* (see lessons on "Machine Construction"), and a point on the other side of the pulley being twice as far from it as the centre of the pulley must move twice as fast; hence, though the instantaneous centre changes to another point on the circumference of the pulley the next instant, still, on the whole, the point D moves twice as fast as the centre of the pulley or the weight W.

DIFFERENTIAL PULLEY-BLOCK.

In the differential pulley-block the sheaves of the top block cannot move relatively to one another

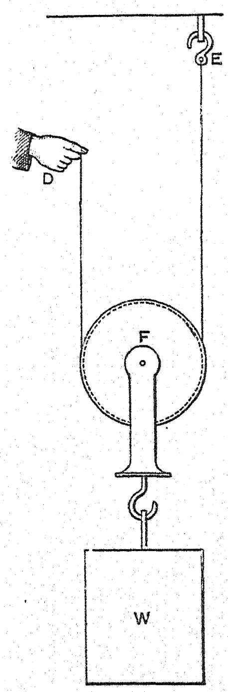


Fig. 28.

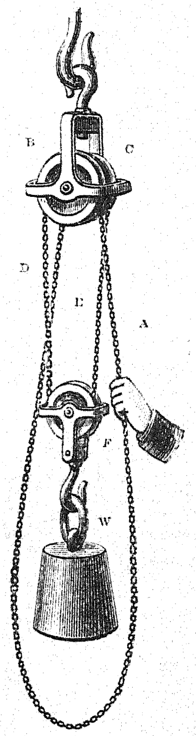


Fig. 29.

as in the case of the ordinary pulley-block. The two grooves of that pulley are of slightly different diameters, but form parts of one solid piece of metal. Thus in Fig. 29 the grooves B and C are different in diameter, but B must rotate once if C goes once round. Let the chain, which is endless, be pulled down at A sufficiently to give one turn to B and C. As B is a little greater and the chain is wound *on* it by the motion, as much chain is wound on as goes once round B, whilst at the same time as much is let off as would go once round C. On the whole, therefore, one might be inclined to say that the chain is drawn up a distance equal to the

circumference of B *minus* the circumference of C, the hand at A acting through a distance equal to the circumference of B. But from the principle just explained in relation to the *movable* pulley the weight is only raised *half the amount by which the chain on the whole is drawn up*. Hence the rule is: if P is the pull exercised by the hand at A, and W is the load raised steadily—

$$P \times \text{circumference of } B = W \times \tfrac{1}{2} \text{ difference of circumferences of } B \text{ and } C,$$

or the hypothetical mechanical advantage

$$\frac{W}{P} = \frac{\text{circumference or diameter of } B}{\tfrac{1}{2} \text{ difference of circumferences or diameters of } B \text{ and } C.}$$

THE CHINESE WINDLASS

shown in Fig. 30 is similar in principle to the differential pulley-blocks, and its hypothetical law is that

The force P × the circumference (or diameter) of

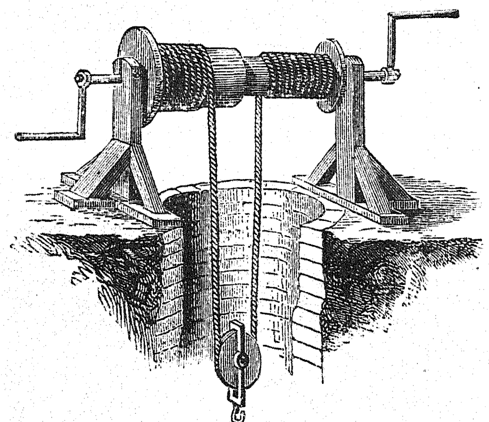


Fig. 30.

the circle described by the handle = the load W × half the difference of the circumferences (or diameters) of the two parts of the axle.

The mechanical advantage, neglecting friction, is the ratio of the multiplier of P to the multiplier of W.

MECHANICAL ADVANTAGE OF LEVERS.

This matter has already been mentioned in a different form.

The student will readily see from what has been given in this connection that if only two forces, P and W, act on a lever, the mechanical advantage of the lever is the ratio of P's arm to W's arm, *i.e.*, the perpendicular distance of the force P from the fulcrum divided by the perpendicular distance of the weight W from the same place. If the forces are, as usual, parallel, these distances may be measured along the lever itself, whether the lever is at right angles to the forces or not as the *ratio* of the distances will be the same. Usually, however, more

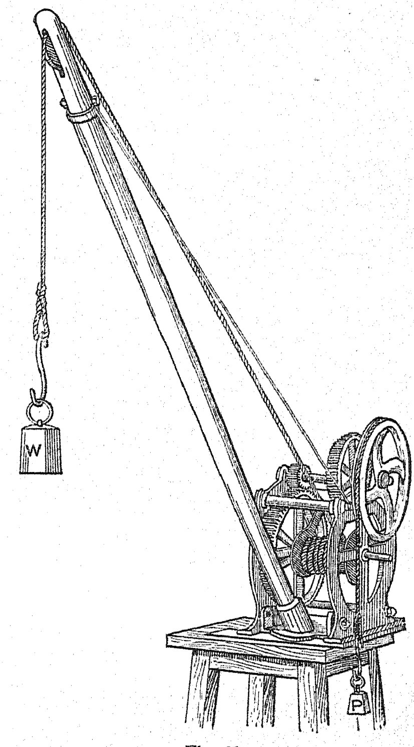


Fig. 31.

than two forces act on a lever, and its mechanical advantage cannot be stated in a simple form.

Hydraulic machines, which are of so much interest and utility nowadays, will be dealt with in the next lesson.

REAL MECHANICAL ADVANTAGE.

The actual mechanical advantage of a machine is not constant, and can be obtained, under given conditions, only by experiment. In closing the present lesson a brief explanation of such an experiment will now be given. The experiment in question was conducted on a small hand crane such as is used for raising weights by manual labour. A view of the machine is shown in Fig. 31. For the purposes of the experiment the handle has been replaced by a pulley or wheel with a groove in the rim, round which a cord is wound, a weight, P, at the end of this cord raising a larger load, W, with a steady motion. The weight P represents the force which would have to be applied to the handle to raise the same load. Various loads are employed, and, by trial, the proper value of P—

necessary to overcome the friction of the machine and raise the load W with a uniform velocity—is determined in each case.

It is necessary to know the velocity-ratio of the machine, which is found either by measuring directly the distance which P falls whilst W rises a certain known distance, or by a calculation of the sizes of the various wheels, etc., involved in the operation. In this experiment it was found that P fell 56·1 inches whilst W was raised 3 inches, hence the velocity-ratio came to $\frac{56 \cdot 1}{3}$ or 18·7. In other words, if there were no friction the application of a force equal to the weight of 1 lb. at P would raise 18·7 lb. at W.

The actual results obtained are given in the following table:—

EFFICIENCY OF CRANE.

Table of Results (velocity-ratio, r, = 18·7).

W = Load raised, in lb.	P=Force applied to Handle, in lb.	$\frac{W}{P}$=Real Mechanical Advantage.	Efficiency $= \frac{W}{r \times P}$.
14	1·22	11·48	·61
28	2·125	13·18	·70
42	3·00	14·00	·75
56	3·91	14·32	·765
70	4·80	14·58	·77
84	5·71	14·71	·78
98	6·58	14·88	·79
112	7·52	14·90	·797
126	8·40	15·00	·80
140	9·30	15·05	·805
154	10·21	15·08	·807
168	11·08	15·16	·81

It will be seen from this table that the mechanical advantage is *not* 18·7, but varies from about $11\frac{1}{2}$ to 15, probably increasing slightly for higher loads but never reaching the theoretic value 18·7. An experiment like this is very instructive, more especially if the experimenter be careful to properly arrange and lay down his results. He should carefully plot on squared paper any of the sets of variables —say load W and mechanical advantage—in order to see *how* the variation of load affects the other quantity. To be able to use squared paper readily, and to understand the results obtained on it, are the first essentials of a modern scientific education. A sheet of squared paper can be bought for a halfpenny or less, but it is of enormous service in arranging the results of practical tests of almost all kinds. The two things referred to above, viz., load and mechanical advantage, have been laid down on such a sheet and are shown in Fig. 32: units of distance horizontally representing units of load, and in a similar way values of the ratio $\frac{W}{P}$ are represented by vertical distances, the scales being arranged to suit the figures involved. It is not at all necessary that the *same* scale be adopted in both directions. It is evident that any one value of the mechanical advantage of the machine, say 14, is connected with a definite value—42 in this case—of the load W. Hence these two distances, or "co-ordinates," as they are called (14 and 42), intersecting in a point, give one point on the curve and others are obtained in a similar way, the curve being drawn in the best mean position among

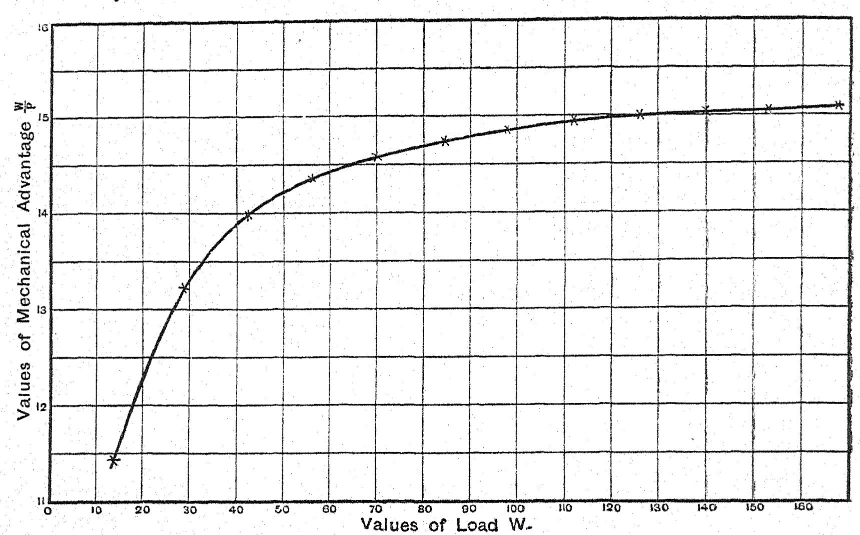


Fig. 32.

these points. The curve itself is a *picture* or *trace* of the law connecting the two things plotted; if the law is a simple one, the curve is of a simple kind—say a straight line as in Fig. 33—whereas if

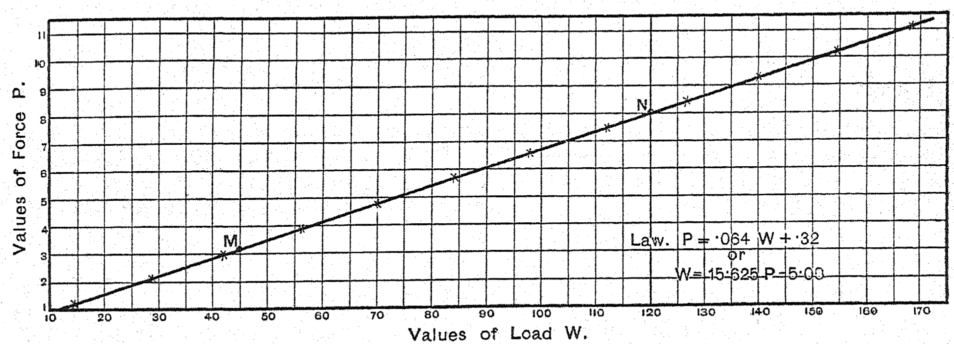


Fig. 33.

the law is more complex the curve is of a higher class.

In Fig. 33 values of P and the corresponding values of W have been laid down, and it will be seen that the curve is of the simplest kind. The law of any of these curves, if required, can be obtained by a well-known mathematical process, but in the case of the curve shown in Fig. 33 the method is so simple as to warrant a reference.

The general law of such a curve is $y = ax + b$, y being the variable represented vertically, and x that represented horizontally on the paper, a and b being numbers depending on the slope of the line and on its position on the paper. In the particular case before us the general law evidently is $P = aW + b$, since P is shown vertically and W horizontally.

To find a and b. Choose any point *on the curve*, say, the point marked M:—

$$\text{Here } P = 3{\cdot}2$$
$$\text{and } W = 45.$$

Again choose another point, say N: here $P = 8$, $W = 120$. Putting these values into our general law, $P = aW + b$, we get the two equations

$$3{\cdot}2 = a \times 45 + b$$
$$8 = a \times 120 + b$$

and by subtraction $4{\cdot}8 = \quad 75a$ or $a = {\cdot}064$.

Putting this value of a into one of the equations, we get $b = {\cdot}32$, and hence our law is

$$P = {\cdot}064W + {\cdot}32.$$

This shows us the force required to raise any given load, and we see from it that the force necessary to overcome the friction of the machine unloaded, *i.e.*, when $W = 0$, is ·32 lb.

It must be remembered that this was a small machine and in good order, but the same method would be followed with a larger machine. The reader should plot columns 1 and 4 to see how the efficiency of the machine varies as the load is increased.

By attaching the hand-wheel to another axle and putting an extra wheel into gear the velocity-ratio of the crane can be increased to about 56, and by a similar process to that just described the law of the machine, its mechanical advantage, and also its efficiency for various loads may be obtained.

The foregoing will, however, be sufficient to enable the reader to understand or carry out such tests.

ELECTRICAL ENGINEERING.—IV.

By Edward A. O'Keeffe, B.E.,
Senior Demonstrator in Electrical Engineering, City and Guilds of London Technical College, Finsbury.

[*Continued from p.* 192.]

RING AND DRUM ARMATURES — SHUNT, SERIES, AND COMPOUND WOUND DYNAMOS.

The condition of affairs is represented graphically in Fig. 15, where the ordinates or vertical distances represent the E.M.F. being generated at any instant of the coil's revolution, and the abscissæ or horizontal distances represent at the same instant the angle through which the coil has turned from the zero position. It may be noticed that the line here shown forms a perfect sine curve, and such it would be, provided the coil was turning in a uniform magnetic field. As this condition seldom exists in practice owing to the distortion due to various causes, the curve is more or less distorted in consequence. The current which would be sent into the external circuit from this machine would be alternating. If a split tube—such as

that in the Pixii dynamo—was used as a commutator, the currents would all flow through the external circuit in the same direction, but they would still rise to a maximum and fall to zero

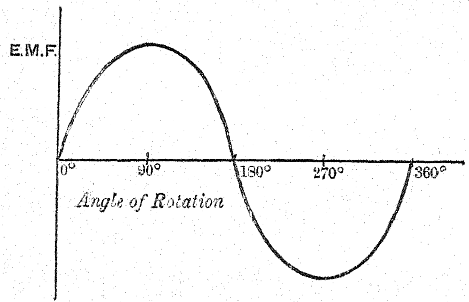


FIG. 15.—ALTERNATING E.M.F.

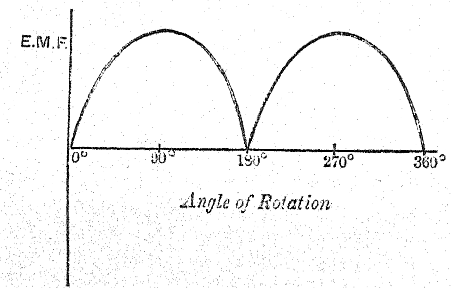


FIG. 16.—RECTIFIED E.M.F.

twice during each revolution. This state of things is represented graphically in Fig. 16, on the same scale as in Fig. 15. The line now consists of two sine curves, but in this case all the values for the E.M.F. are positive, that is to say, they are above the zero line. The E.M.F.'s are certainly reversed in the coil itself, but the brushes which lead the current into the external circuit are reversed at the same instant. The above diagram represents the effective E.M.F. which sends the current through the external circuit at any instant of the armature's revolution.

THE DRUM ARMATURE.

By using a single coil of wire—no matter how many turns there may be on it—and a split-tube commutator, the current obtained is not continuous, as it rises to a maximum and falls to zero twice during each revolution. If the core consisted of an elongated drum-shaped piece of iron, and the coil was wound on it, the effect would be practically the same; but if a second coil was wound on it at right angles to the first, the current that would now be generated would be continuous, though not of uniform strength. If a third coil was wound on, the current would still be continuous, and more nearly uniform; in fact, the greater the number of independent segments or coils of wire that are wound on the armature, the more nearly will the current be of uniform strength during the different periods of the armature's revolution. Special arrangements must, of course, be made for directing all these currents to flow in the same direction through the external circuit. The commutator, instead of consisting of a split tube, which sufficed for the single coil, will be made up of as many insulated segments as there are coils on the armature. A diagram of a drum armature is shown in Fig. 17. The armature here shown contains eight separate segments, four of which are omitted, with a commutator consisting of eight insulated pieces to which these coils are attached. The north pole of the field-magnet, N, is supposed to be situated to the right, and the south pole, S, to the left of the armature, whose direction of rotation is shown by the large arrow-head. The thick pieces, marked *a*, *b*, *c*, *d*, *e*, *f*, *g*, and *h*, are the insulated metallic segments of the commutator, and the coils are attached to these in the manner shown. The brushes that convey the current to the external circuit are supposed to rest on the segments *c* and *g*, whilst the external circuit is indicated by the dotted line.

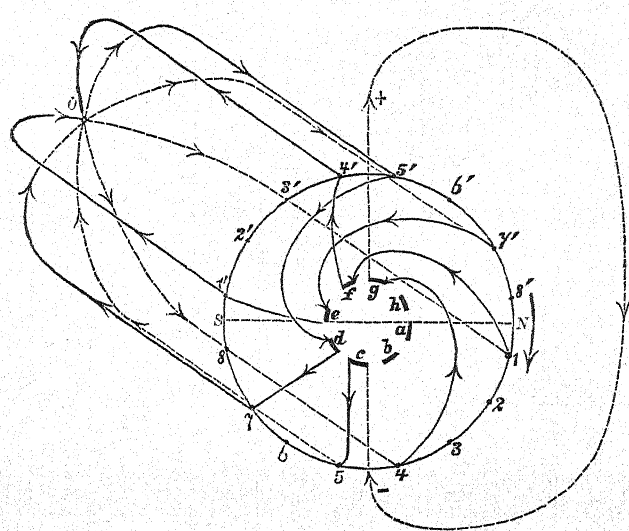


FIG. 17.—DIAGRAM OF DRUM ARMATURE.

Starting at segment *g*, it will be seen that a coil is joined between it and the adjacent segment *f*, and that the course of that coil is from *g* to 4, then to 0—where all the coils cross—then to 4′, and then to the segment *f*. The upper half of this coil is approaching the north pole of the field-magnet, whilst the lower half is approaching the south pole, and in consequence currents will be induced in opposite directions—relative to space—in these parts, but in the same direction relative to the course of the wire. From *f* the current goes to 1, 0, 1′, and so back to the next segment of the commutator *e*. The direction of the current generated in this section of wire is shown by the arrow-heads, and it will be seen that both currents flow through the wires in the same direction. Following the course of the current induced in the section between *e* and *d*, and between *d* and *c*, it will be seen that all four currents flow through the coils in the same direction, so that if the brushes were situated at the extremities of the vertical diameter of the commutator, they would be supplied by the current generated in all these four sections. These coils generate E.M.F.'s whose strengths depend upon their positions in the field. Each coil generates an E.M.F. whose strength varies from zero up to a maximum—as shown in Fig. 15—according to its position in the field; but as the current sent into the external circuit is driven by the sum of the E.M.F.'s of the individual coils, there is very little variation in its strength. It is clear that the greater the number of sections of wire on the armature the more uniform will be the strength of the current sent through a given external resistance, but on the other hand there is of necessity a practical limit to the number of segments on the commutator which corresponds to the number of sections on the armature

THE RING ARMATURE.

The Gramme ring is the standard type of ring armature, and is illustrated diagrammatically in Fig. 18. The core of this ring, A N B S, consists of wrought iron, upon which are wound eight coils of copper wire, represented in the diagram by single turns marked 1, 2, 3, 4, 5, 6, 7, and 8, the junction of each pair of these coils being joined to a segment of the commutator. The direction of rotation is shown by the large arrow, and the poles of the field-magnets are directly above and below the ring; the south pole is placed above, and the north pole below.

It is found that whether the ring be at rest or in motion, its core will always be magnetised by the action of the field-magnets in the same manner; thus, that part which is nearest to the north pole of the field-magnets will be converted into a south pole, and is marked S; while that part which is nearest to the south pole will be a north pole, and is marked N. This statement is not strictly true when the ring is in motion and a current flowing, as the polarity of the core will be slightly displaced in the direction of rotation, for reasons that will be subsequently dealt with. The lines of force that pass from the north to the south pole of the field-magnet nearly all pass through the wrought-iron

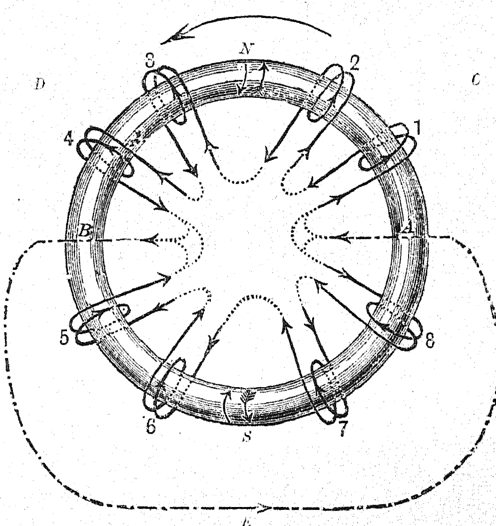


Fig. 18.—Theory of the Gramme Ring.

core of the armature, few, if any of them, passing through the interior portion of the ring; and during the rotation of the armature we may look upon the directions and the number of these lines as constant.

Let us consider what happens in coil 3 as it moves into different parts of the field. When it was in the position marked N, it lay parallel to the lines of force, but enclosed none of them. In moving up to its present position it gradually enclosed, and consequently cut, lines of force, and therefore had a current generated in it. The direction of this current must give the coil in which it circulates that polarity which will be attracted by the pole which it is leaving, thus exerting a force which tends to stop the motion of the armature. Coil 3 is leaving the south pole of the field-magnet, and consequently its face, which is turned towards that pole, must exhibit north polarity—that is to say, the current must circulate in it in a

counter-clockwise direction when viewed from that side. This direction is shown on the coil by the position of the small arrow-head. This state of things may be more clearly seen in Fig. 19, which shows a single turn of wire receding from a south

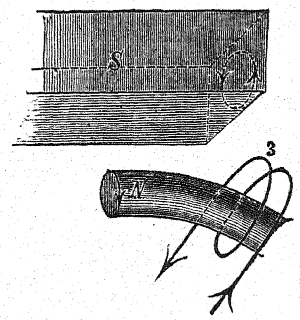


Fig. 19.—Theory of the Gramme Ring.

pole, S, on the face of which is drawn the Amperian current. The coil must exhibit north polarity towards the south pole of the magnet, as is shown by the direction of the current. As the coil moves up to position 4 (Fig. 18) the direction of the induced current is still the same; but since the coil is cutting fewer lines of force at this point—though there are more of them passing through it—the strength of the current is less. When the coil has reached the position marked B, it has enclosed the maximum number of lines of force, and therefore the number is just about to diminish. The instant the coil passes this point, the number of lines passing through it begins to diminish, and an E.M.F. is therefore generated in it, but in the opposite direction to the previous one. This E.M.F. is feeble at the commencement, but increases in strength as the coil moves up from B to S. Since the direction of the current is reversed in it, it will exhibit a north polarity on its lower face, which will be repelled—as was to be expected—by the north pole of the field-magnet, which is situated below the armature. This force of repulsion is exerted till the coil has reached its lowermost position, after which it begins to recede from the field-magnet, and consequently to turn its other face towards it; this face clearly has south polarity, which will exert a force of attraction on the field-magnet. The directions of all these induced currents are indicated on the coils by the arrow-heads, and it will be seen that starting from the point B, all these currents flow towards the point A. The brushes that rest on the commutator, and convey the currents to the external circuit, should be placed at the points A and B. The current will then come out at A, flow through the external circuit E, and return to the armature through the brush situated at B.

The segments of the commutator which are in contact with the brushes have each two coils joined to them in which currents are flowing in opposite directions; these currents unite at the segment and flow into the external circuit, as is illustrated diagrammatically in Fig. 20. Here the currents enter the coils 1 and 8 at the points C and D, unite at the segment A, and flow to the external circuit through the brush B. It will be noticed that the coil is doing the minimum amount of cutting of lines of force at the moment when commutation takes place.

So far we have assumed the existence of a magnetic field of sufficient strength for the satisfactory working of the machine, but the providing of such a field is a matter of paramount importance, and it is in this direction that the greatest advance has been made in modern dynamos. The field may be produced by permanent steel magnets—as was invariably done in the older machines, and as is still done in a few isolated cases—and when such is the case the dynamo is called a *magneto*; but the

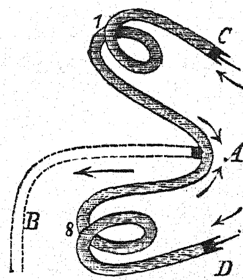


Fig. 20.—Gramme Ring: Current from Two Adjacent Coils.

more usual method is to produce it by means of powerful electro-magnets. The electro-magnets entail the expenditure of a certain amount of energy in the form of current, and in order to provide this, it was suggested by Dr. Werner Siemens, in 1867, to send the current which was generated in the armature, or a portion of that current, through the coils of the field-magnets, and thus to dispense with the necessity for a second current-generator, such as a primary battery, as an auxiliary to the dynamo. This method is almost universally adopted at the present day for continuous-current dynamos; for alternate-current dynamos a separate exciting source is usually employed, though it must not be assumed as impossible that an alternator should be self-exciting. The usual methods of utilising the current generated in the armature for exciting the field-magnets are shown in the

following diagrams, in which the armature is denoted by a circle on which the brushes rest, and the field-magnets by the rectangle on which the wire is wound.

Fig. 21 shows what is known as *series winding.* All the current generated in the armature flows through the coil of wire which is wound on the field-magnets, then through the external circuit, and then back to the other pole of the dynamo. In

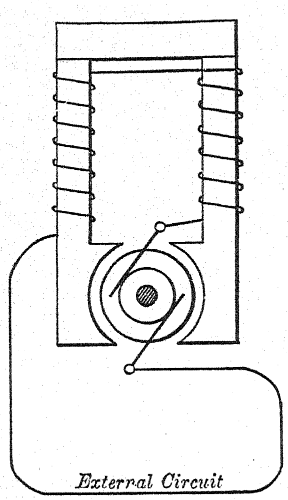


Fig. 21.—Series Dynamo.

these dynamos the wire on the field-magnets is usually of large diameter, of comparatively low resistance, and there are not very many turns of it. Dynamos used for lighting arc-lamps, or wherever a constant current is required, are generally wound in this manner.

Fig. 22 illustrates what is known as *shunt winding.* It will here be noticed that the current generated in the armature does not all flow either through the field-magnets, or through the external circuit. It is divided at the point *b*; part flows through the field-magnets, part through the external circuit, and they unite at the point b_1, from which they return to the armature. Both types of machines are extensively used.

The shunt machine cannot provide either a constant current or a constant E.M.F. under variable conditions in the external circuit. It is largely used for electro-plating and charging accumulators, and in connection with the latter, which act as regulators on it, is largely used for incandescent lighting, or for any situations where constant E.M.F. is required.

Fig. 23 illustrates what is known as *compound winding,* which, as may be seen, is a combination of both shunt and series winding. The thin coil is the shunt winding, and consists of many turns of thin copper having a high resistance. The thick coil consists of a very few turns of very thick wire

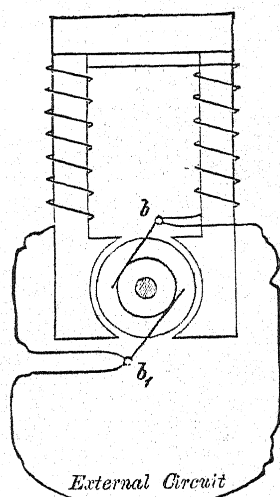


Fig. 22.—Shunt Dynamo.

having a very low resistance. This combination of shunt and series winding is used extensively for incandescent lighting, with or without accumulators. It enables the dynamo—within an extremely large

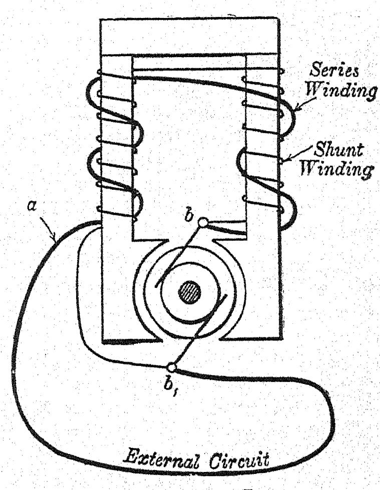


Fig. 23.—Compound Dynamo.

range of working—to provide constant E.M.F. at the terminals of the lamps. There is another modification of compound winding known as long-shunt winding, which is not illustrated, but which

can be easily understood from Fig. 23. In Fig. 23 the shunt coil is directly attached to the brushes b and b_1; in long-shunt one end of the shunt is attached to the brush b_1, and the other end to the junction of the series winding with the external circuit; this point is marked a. These are the standard methods of winding continuous current machines.

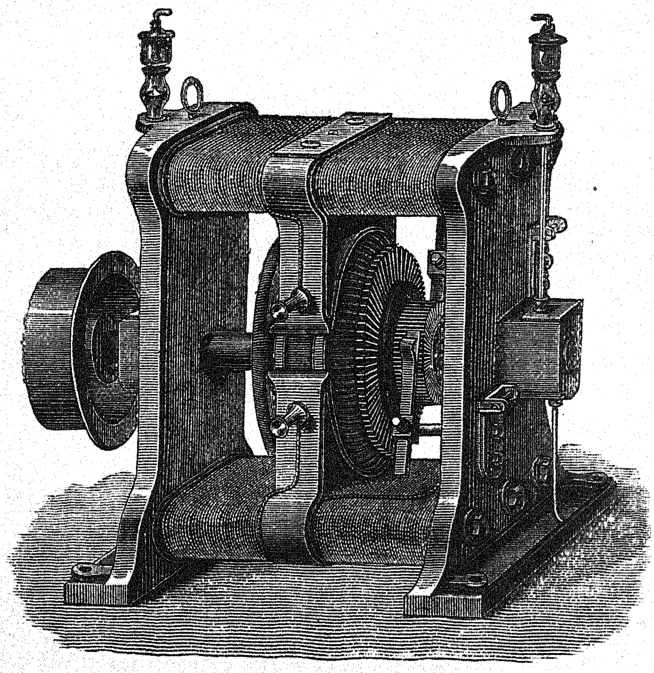


Fig. 24.—Gramme Dynamo.

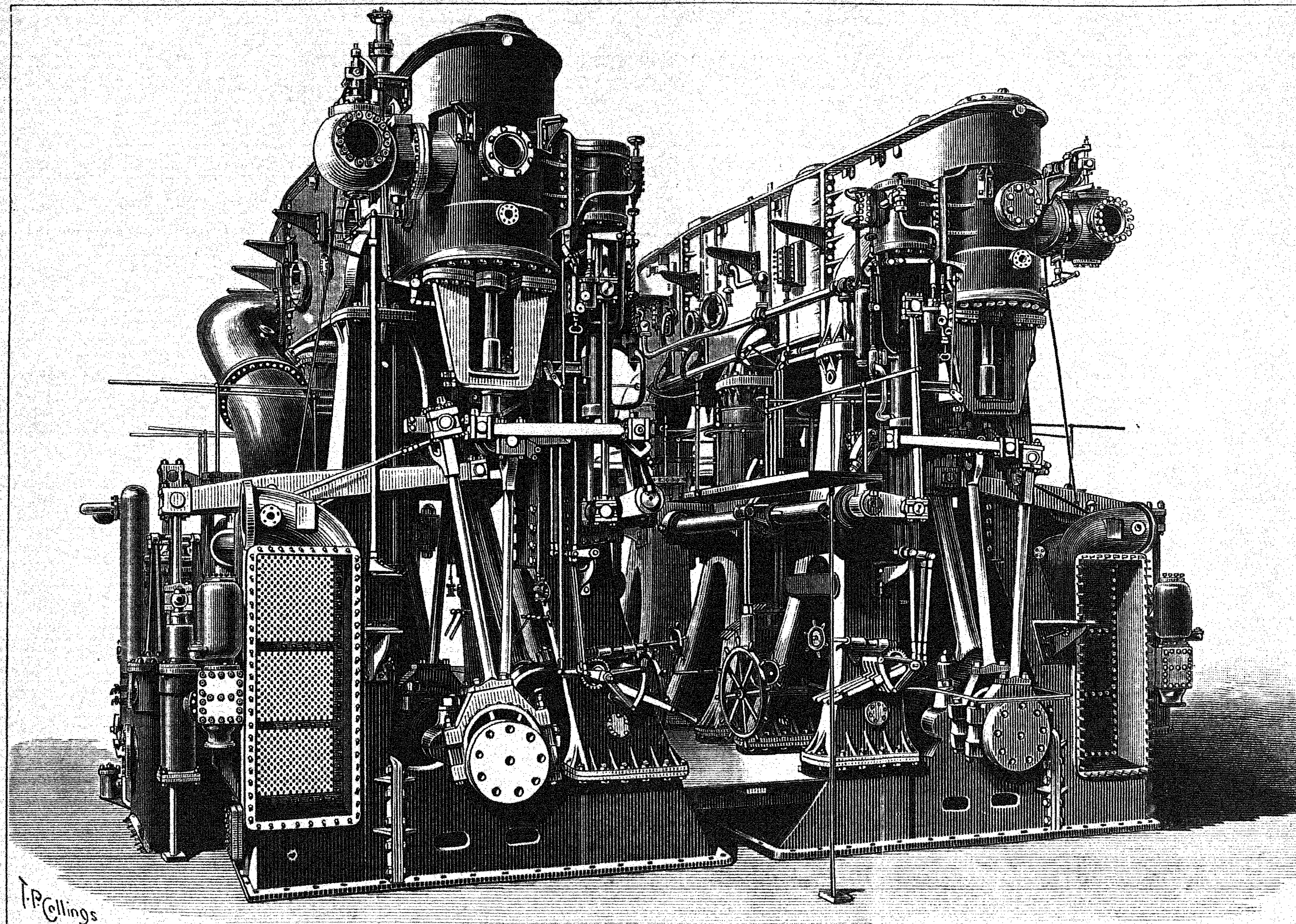
RING DRUM DYNAMO OF GRAMME

Turning now to the application of the principles which have just been laid down, we see in Fig. 24 the general arrangement of the gramme dynamo, and in Fig. 25 the manner in which the circuits are arranged.

In this machine the field is produced by means of two powerful horse-shoe electro-magnets (Fig. 25), N A S and N_1 B S_1, wound so as to form a double north pole above—at the point N N_1—and a double south pole below—at the point S S_1. The lines of force, therefore, pass vertically downwards from N N_1, through the armature R, to the south pole S S_1. It will be noticed in Fig. 24 that at the place where the two north poles meet the iron is considerably expanded, so as to embrace about one-third of the armature, and that the pole-piece thus formed is brought as close to the wires on the armature as mechanical considerations will allow; also, that a similar method of construction is adopted where the two south poles meet. About two-thirds of the armature is thus embraced by the pole-pieces of the electro-magnets, leaving about one-sixth of the armature open at each side. These open spaces are often covered in by means of a brass plate, or any other non-magnetic metal, which serves the double purpose of strengthening the framework of the machine, and preventing accidental damage to the wires of the armature while in motion. The space between the iron core of the armature and the faces of the pole-pieces, or polar faces as they are usually called, is known as the *air-gap*, and the distance between the iron of the armature and the polar face is spoken of as the *length of the air-gap*. In the dynamo under notice the air-gap is partly occupied by the copper wire in which the current is generated, partly by the insulating material surrounding the wire, and partly by the clearance space prescribed by mechanical considerations. In all well designed dynamos the length of the air-gap is reduced to the smallest possible amount, the necessity for which will be apparent when the calculations are gone into in a later chapter.

In Fig. 26, which is a section through the iron of the armature and pole-pieces, the extremities marked a, b, a_1 and b_1 are called the *horns* of the pole-pieces, and when the dynamo is running in the direction indicated by the arrow, the two horns a and a_1 are called the *leading horns*, and the two b and b_1 the following, or *trailing horns*.

The armature R is mounted on the steel shaft A B, which runs in bearings carried by the two substantial upright iron castings at either end of the dynamo. It consists of a coil of insulated copper wire forming a continuous spiral round an iron core. By the side of the armature is shown the commutator, with the brushes 1 and 2 resting on it and taking off the current, which is then sent round the field-magnets before flowing into the external circuit. It will be seen that each bar



ENGINES OF THE R.M.S. "SCOT."

(*Twin-screw, triple-expansion, 12,000 indicated Horse Power.*)

BUILT BY MESSRS. DENNY & CO., DUMBARTON.

of the commutator is permanently connected to a point on the spiral, which can therefore be looked upon as being made up of numbers of sections,

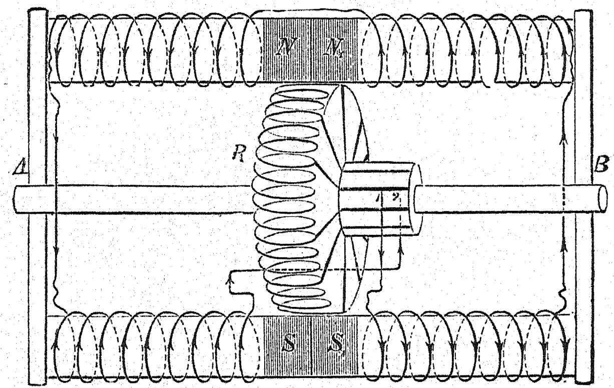


Fig. 25.—Diagram Illustrating the Theory of the Gramme Machine

each of which contains the same number of turns or loops of wire. The number of segments on the commutator clearly corresponds with the number of sections of wire on the armature, but a section may contain any given number of turns of wire. For generating high E.M.F.'s and small currents, each section consists of a large number of turns of thin wire, and for large currents and small E.M.F.'s the sections may contain as few as a single turn. The number of segments on the commutator is no indication of the number of turns on the armature.

The actual construction of the armature is illustrated in Fig. 27. The core is flattened, and consists of a bundle of well-annealed soft wrought-iron wires, shown in section A. These wires are

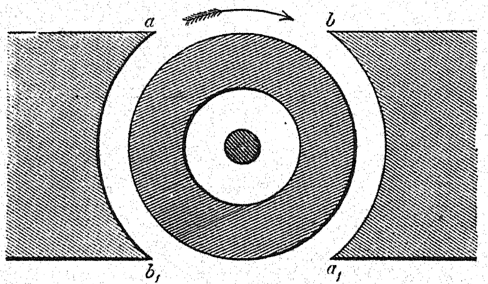


Fig. 26.

used in preference to a solid core, since they prevent the formation of eddy currents, and since they are more quickly magnetised and demagnetised than the solid substance. The coils consist of well-insulated copper wires wound separately, and then slipped on over the core. The junctions of the coils are soldered to the copper strips, R, which are bent at right angles, and which protrude beyond the ring. When the ring has been completely wound, and the ends A and B are closed, the strips R project beyond the armature and form a kind of hollow cylinder with a space between each strip. These spaces are filled with some insulating substance—usually mica—and the strips turned down so as to form the commutator. A wooden ring is shown separating the coils from the strips.

This dynamo generates a continuous current, and as the number of sections on the armature is usually large, the E.M.F. does not appreciably change at different parts of each revolution. The machine just described is series wound—all the current generated in the armature flowing round the field-magnet circuit—but it could be made either shunt or compound wound if required.

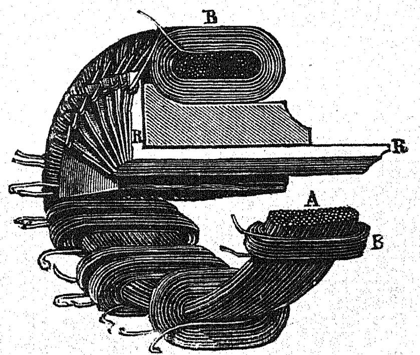


Fig. 27.—Section of Gramme Ring.

THE STEAM ENGINE.—IV.

By Archibald Sharp, B.Sc., Wh.Sc., A.M.I.C.E.,
Instructor in Engineering Design at the Central Institution of the City and Guilds of London Institute.

[*Continued from p.* 153.]

THERMODYNAMICS OF STEAM VAPOUR.

The thermodynamics of a perfect gas are simpler than the thermodynamics of steam, and have been given in order to lead up to the latter. Let us now consider the effect of application of heat to water.

If we take a pound of ice, at a temperature of 0° F. and subject to the ordinary pressure of the atmosphere, and apply heat to it, its temperature produces no rise of temperature, but converts some of the ice into water. To convert the pound of ice at 32° F. into water of the same temperature 144

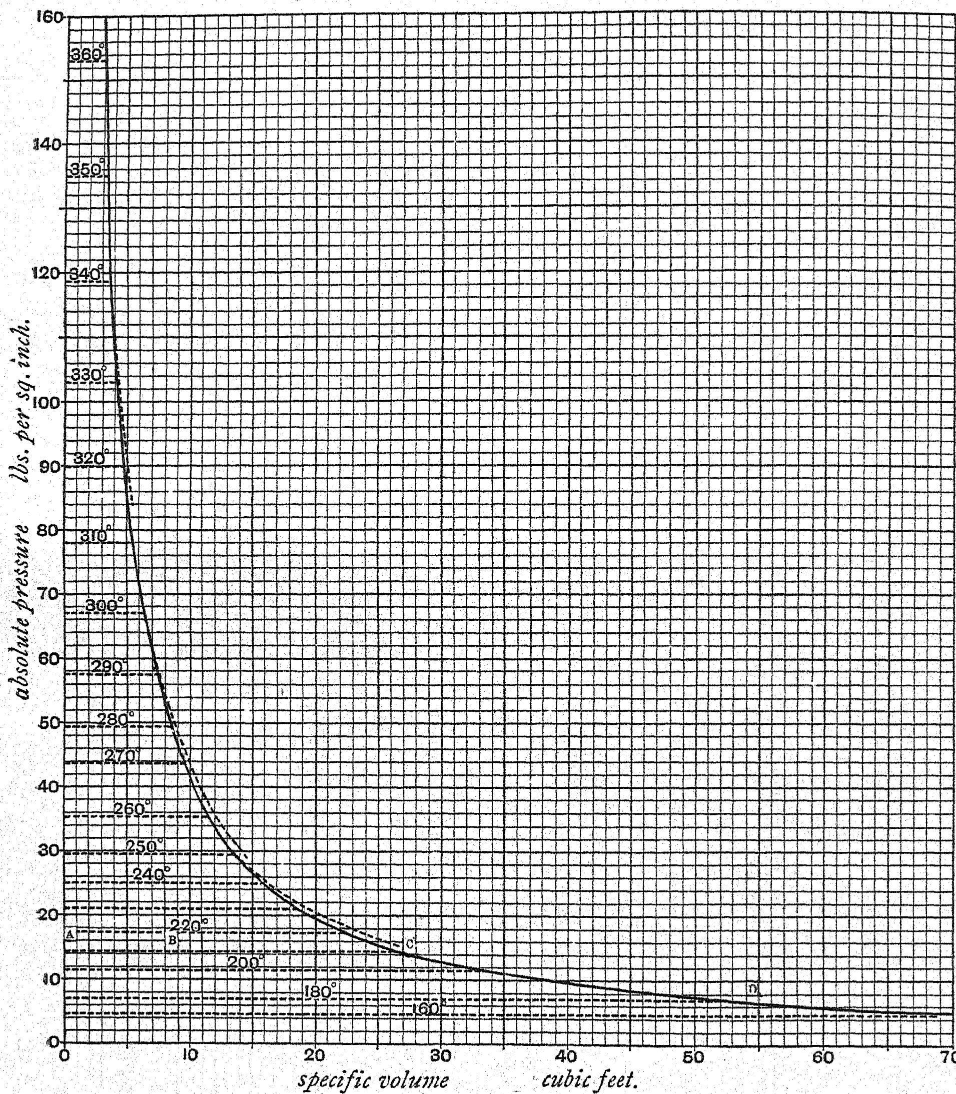


Fig. 36.—Isothermals of Steam and Water.

will gradually rise, and about half a thermal unit is required per degree rise of temperature; that is, its specific heat is about ·5. This increase of temperature, which is accompanied by an increase of volume, takes place until a temperature of 32° is reached, when a further application of heat thermal units are required. This heat which is not sensible to the thermometer is called "latent heat"; and heat required to convert a substance from the solid to the liquid form is called the "latent heat of fusion," thus the latent heat of fusion for water is 144 thermal units. The water

at 32° is of less volume than the ice at 32°. When the ice is all melted and more heat applied, the temperature of the water rises nearly uniformly at the rate of 1° per thermal unit. The volume at the same time diminishes until a temperature of 39° is reached; at higher temperature an increase of temperature produces an increase of volume. When a temperature of 212° is reached, the further application of heat produces no rise of temperature, but converts part of the water into steam. To convert a pound of water at 212° into steam at 212°, 966 thermal units are required. This is called the *latent heat of vaporisation*. The volume of 1 lb. of steam at 212° is 26·47 cubic feet, or 1,650 times the volume of water at the same temperature. If more heat be applied the temperature rises, the specific heat being ·4805, and the volume increases at the same time. The steam is now called superheated steam, and the relation between temperature and volume is approximately the same as for a perfect gas, the approximation being closer the higher the temperature above the boiling-point. Steam at the temperature of the boiling-point and free from watery particles is called "dry saturated steam." In other words, "dry saturated steam" is steam in such a condition that if heat be abstracted from it part of the steam would be condensed into water, the temperature remaining constant, and if heat be added to it, its temperature would rise. Wet steam is a mixture of steam and water, and the addition or subtraction of heat merely alters the proportion of steam to water in the mixture, while the temperature remains unaltered. In the phenomena described above, it must be noted that the pressure is supposed to remain the same throughout, and is equal to the ordinary pressure of the atmosphere.

If now the water be subject to a greater pressure than that of the atmosphere, the phenomena observed at the lower temperatures will be the same as described above, but the temperature at which steam is formed will be higher. For instance, if the pressure on the water or steam be 15 lb. above atmosphere or 30 lb. absolute, the boiling-point will be 250° and the latent heat of evaporation will be 939 thermal units, while the volume of the dry saturated steam is 13·49 cubic feet, that is 843 times the volume of the water from which it is generated. Our knowledge of the specific volume of dry saturated steam is due to Regnault. Rankine expresses the results of his experiments by the formula

$$p\,v^{\frac{17}{16}} = \text{constant} \quad \ldots\ldots\ldots\ldots\ldots(1).$$

Practically it is more convenient to get the specific volume v corresponding to a given pressure p from a table (*see* Table 1); but if a table is not accessible, v may be calculated provided the value of v for any one value of p is known.

TABLE 1.

Relation between Pressure, Temperature, and Specific Volume of Dry Saturated Steam.

Absolute Pressure in lb. per Square		Temperature.		Volume of 1 lb. in Cubic Feet.
Inch.	Foot.	Fahr.	Absolute.	
p	P	t	T	v
·085	2·24	32	493	3,390
1·0	144	102	563	327
2·0	288	126	588	171
3·0	432	142	603	117
4·0	576	153	614	89
5·0	720	162	623	72
6	864	170	631	61
7	1,008	177	638	53
8	1,152	183	644	46
9	1,296	188	649	42
10	1,440	193	654	38
11	1,584	198	659	34
12	1,728	202	663	32
13	1,872	206	667	29·4
14	2,016	210	671	27·4
14·7	2,116·8	212	673	26·2
15	2,160	213	674	25·7
16	2,304	216	677	24·2
17	2,448	220	681	22·8
18	2,592	223	684	21·7
19	2,736	225	686	20·6
20	2,880	228	689	19·6
25	3,600	241	702	15·9
30	4,320	251	712	13·4
35	5,040	259	720	11·6
40	5,760	267	728	10·2
45	6,480	274	735	9·1
50	7,200	281	742	8·3
55	7,920	287	748	7·6
60	8,640	293	754	7·0
65	9,360	298	759	6·5
70	10,080	303	764	6·0
75	10,800	308	769	5·7
80	11,520	312	773	5·3
85	12,240	316	777	5·0
90	12,960	320	781	4·8
95	13,680	324	785	4·5
100	14,400	328	789	4·3
110	15,840	335	796	4·0
120	17,280	341	802	3·6
130	18,720	347	808	3·4
140	20,160	353	814	3·2
150	21,600	358	819	2·95
160	23,040	363	824	2·78
170	24,480	368	829	2·63
180	25,920	373	834	2·49
190	27,360	377	838	2·37
200	28,800	382	843	2·25
250	36,000	401	862	1·83
300	43,200	417	878	1·54

The curve represented by the equation $p v^{\frac{17}{16}}$ is called the "saturation" curve for steam. It is represented by the full line on Fig. 36. The

student must clearly recognise that this curve is not an expansion curve, but merely expresses the relation between the volume of 1 lb. of dry saturated steam and its pressure.

The relation between the pressure and temperature of dry saturated steam cannot be expressed by an equation of such a simple form, and a table is used for the purpose (*see* Table 1), or the value of v and t for any given value of p may be read off from Fig. 36 with a degree of accuracy sufficient for some purposes.

Isothermals of Steam.—It is instructive to compare the isothermals of a liquid and its vapour with that of a perfect gas. Let us draw the isothermal for water and steam corresponding to a temperature of 212° F. Suppose a pound of water at 212° F. be enclosed in a cylinder fitted with a piston, it will occupy a volume ·0169 cubic feet at the ordinary pressure of the atmosphere, say, 14·7 lb. per square inch. Let the point A represent this state. If now the piston be drawn out while the temperature be kept at 212°, some water is evaporated and the pressure still remains 14·7 lb. absolute. The point B represents this state, there being in the cylinder a mixture of water and steam. When all the water is just evaporated the volume is 26·2 cubic feet. This state is represented by the point C. If the piston be pulled farther out while the temperature is kept at 212°, the pressure will fall and the remainder of the isothermal will be a curve C D. The steam is now called superheated, and its properties approximate to those of a perfect gas. If, now, different temperatures be taken and the corresponding isothermals drawn, the points C will form the saturation curve which we have already studied.

Adiabatics of Steam.—In a steam engine cylinder there is usually a mixture of steam and water. In this case the equation of the adiabatic is $p v^n =$ constant. The value of n depends on the initial proportion of steam to water in the mixture. If the total weight of the fluid mixture be 1 lb. while the weight of the steam is x lb., according to Zeuner the value of n may be represented by the formula

$$n = 1·035 + 0·10x \quad \ldots\ldots\ldots\ldots (2).$$

Rankine, who was the first to give an approximate equation for the adiabatic of a mixture of steam and water, gave the formula $p v^{\frac{17}{16}} =$ constant.

This value of n may be considered as an average of those given by Zeuner's formula. The quantity x is called the "dryness fraction" of the mixture. Assuming (1) and (2) to be true,

If in (2) n be $\frac{17}{16}$, 1·0625, we have

$$1·0625 = 1·035 + ·10x,$$

from which $x = ·275$.

Therefore, when the mixture contains 27·5 per cent. of steam and 72·5 of water, the adiabatic expansion curve will be same as the saturation curve for the same quantity of steam, and no condensation of steam or evaporation of water will take place during expansion. For mixtures containing initially a large proportion of steam, n is greater than $\frac{17}{16}$, and the adiabatic is steeper than the saturation curve, consequently there will be condensation during adiabatic expansion. If the mixture contain less than 27·5 per cent. of steam, n is less than $\frac{17}{16}$, the adiabatic is not so steep as the saturation curve, and consequently there is evaporation of some of the water during expansion.

Expansion of Steam in the Cylinder of a Steam Engine.—In the cylinder of a steam engine steam from the boiler is admitted while the piston performs the first part of its stroke. During this part of the stroke the pressure in the cylinder remains constant and nearly equal to the pressure in the boiler. The steam supply is then cut off by the slide valve, and the steam expands as the piston performs the remaining part of the stroke. If the cylinder walls, cover, and piston were of perfectly non-conducting material, the expansion would be adiabatic. But the cast iron from which the cylinder and piston are usually made is a good conductor of heat. During the admission of steam from the boiler the walls of the cylinder and the piston are heated—at least a small portion of their thickness—to about the temperature of the incoming steam. The heat necessary to raise the temperature of the cylinder walls is got from the latent heat of a portion of the steam which is condensed to water of the same temperature. By this initial condensation, although dry saturated steam may be supplied from the boiler, the steam in the cylinder at cut-off may contain as much as 20 or 30 per cent. of water, and in some cases even 50 to 70 per cent. During expansion the temperature of the mixture in the cylinder falls and there is a transfer of heat from the cylinder walls to the steam. The effect of this transfer is to re-evaporate part of the water in the cylinder and raise the final pressure in the cylinder higher than that due to adiabatic expansion.

With an initial condensation of, say, not more than 20 or 30 per cent., we may consider the expansion curve to be a common hyperbola. This will be sufficiently accurate for estimating the form of the indicator diagram that will be given by an engine.

If the initial condensation be greater, the re-evaporation is also greater, and the final pressure will be higher than would be given by drawing a hyperbola through the point of cut-off.

TECHNICAL EDUCATION:

POLYTECHNICS.

By Quintin Hogg.

It has been my lot to hear two definitions of a Polytechnic coming from very different strata of society.

A certain noble lord startled a South London audience by asking them, "What is a polytechnic?" and the reply he gave to his own question was that "it was the outward expression of a desire that there should be something done to raise and unite the different classes of society."

The other definition came to me through a conversation between two ragged boys holding on to the railings in Vincent Square, where I happened to be playing football against Westminster School. One of these lads, recognising me, yelled out my name for the instruction of his friends, and connected it with the Polytechnic. "Vot's a polypicnic?" inquired another boy standing near. "Vy, a place where they learns you everything"; and I am not sure if the ragged boy's solution of the difficulty was not more exact than that of the noble lord's above referred to.

Perhaps one illustration of the difficulty of describing in a short article the sphere and scope of a Polytechnic Institute may be found in the fact that though I am writing this article for the New Technical Educator, I should feel that one on the same subject would be equally in place in an athletic journal, a religious magazine, a secondary education pamphlet, or a book on social subjects. As, however, nothing is so effective in the way of illustration as an object-lesson, I think my best plan will be to take the pioneer Polytechnic as an example, and in describing the various operations there I shall best indicate the lines on which success in such institutes can be best secured.

Many years spent in ragged-school and institute work had brought home forcibly to my mind the thought that every existing institute that I knew of ignored the initial fact that man has more than one side to his character. For instance, there were educational establishments, such as the Birkbeck; there were religious institutions, such as the Young Men's Christian Association; there were athletic clubs and social clubs; but no attempt had been made, so far as I knew, to unite them. On the other hand, no ordinary young man wanted always to be receiving instruction, or boxing, or at a prayer meeting, or in the reading-room; but what he did require was a place where he could do any one of these things as he felt inclined, and where he would have an opportunity of doing them all well. This, then, was the central thought of the Polytechnic: its special connection with technical instruction formed a natural and manifestly needed part of the educational side. To put the matter in another form, the "Poly" seeks to deal alike with the head, the hand, and the heart, and to afford scope alike to the mental, physical, social, and religious activities of young men and women. The response made as soon as it was opened by the class for whom the Polytechnic was intended showed me, clearer than words could tell, that a pressing need had been met. Our own old institute in Long Acre, which had been carried on for many years under a limit of 500 members, was allowed, while the necessary alterations were being made, to double itself, and we moved into the Polytechnic, in September, 1882, 1,000 strong.

The very first night another 1,000 young men booked their names as members, besides hundreds more as students, and it was evident, long before the first winter was through, that we had seriously miscalculated the arrangement of our premises. I had fixed on 2,000 members and students as approximately the number we might expect to have to deal with, and the rooms were all arranged on that supposition. Our first season gave us 6,000 members and students, and we now number over 13,000.

It may perhaps be asked how in the world order is kept amongst the thousands of young men trooping every night into the "Poly," and filling its vast capacities of accommodation to overflowing. The answer is as simple and satisfactory a one as could be desired. No such person as a "chucker-out," or paid keeper of order, is required in the entire building. The members of the Council wear badges, and, when it is necessary, call any member's attention to any particular rule he may be voluntarily or involuntarily transgressing. The fact is that young Englishmen at any rate live up to their surroundings, and if they see that an honest endeavour is being made to meet their wants they may be amply trusted to assist and not to mar the effort. I have scarcely ever taken anyone round the Institute who has not expressed his surprise at the extreme orderly self-government and self-control exhibited by the members. In so large a number, of course, a polytechnic, like any other place, will have its proportion of black sheep; but in a polytechnic rightly conducted there is such a strong feeling in favour of proper behaviour and good order that never once in my whole experience have I known it to be necessary to supplement the gratuitous and often unconscious influence of our own members.

EDUCATION.

We have in all, during the winter, some 500 different classes per week on various subjects.

Our staff of teachers consists of over 100, and, in passes and results, it need fear comparison with no other institution in the kingdom.

Our first care was to approach the Trades Council of London, explain our object, and ask for their co-operation. From the first we have received constant assistance from them, as we arranged that the trade classes should only be open to young men actually earning their bread at the trades taught at such classes; the object of the Polytechnic, of course, being not to flood the market with untrained workmen, but to improve the capacities and knowledge of the workmen that already existed. For instance, we will suppose that a plumber is engaged in a shop where almost his entire time is occupied in outside work. By paying a small fee such a man can attend the technical and practical plumbing classes, and learn the theory of sanitation, the best forms of traps, and can practically carry out internal work. Or, should the case be reversed, he has the opportunity at the "Poly" of learning ridge work, making gutters, hammering out lead so as to obtain any shape required, etc. A simple list of our classes would occupy nearly as much space as is allowed to this entire article; suffice it to say, therefore, that we have tried to make the class-list as catholic as possible, always giving preference to those classes which would assist trades and manual labour. Brick cutting and laying, construction of arches, architecture, taking out quantities, boot and shoe making, carpentry, cabinet-making, carriage-building, electrical engineering, electro-metallurgy, plastering, typography, watch-making, goldsmith's work, photography, upholstery, staircase construction, tailors' cutting, chasing and repoussé work, etching, electro-plating, metal turning and fitting, wood-carving, and many other kindred subjects are dealt with in these evening classes. The fees range, as a rule, from 3s. to 5s. for members, and from 4s. to 7s. 6d. for non-members, though some few class-fees go higher or lower. If any member wishes another class added to the list, we tell him that if he will obtain the names of ten or twelve other members who will undertake to join the class we will provide the instructor and try it for a session.

So far for the technical and trades side. Then there is a regular School of Art, with drawing from life, painting, modelling, book illustration, etc., attended by some 800 or 1,000 students. In this we also lay ourselves out specially for Applied Art—that is to say, for that side of Art which is of practical service in trade work. There is a Photographic School, where every description of photography is taught, and which has been exceptionally successful.

Then there are science classes, where building construction, the principles of agriculture, organic and inorganic chemistry, geology, geometry, hygiene; sound, light, and heat; experimental physics, higher mathematics, physiology, steam and the steam-engine, etc., are dealt with; and there are commercial and general classes covering typewriting, shorthand, book-keeping, French, German, Latin, Spanish, Italian, etc. There are also some special classes for preparing for Chamber of Commerce certificates, for the London Matriculation, for Civil Service examinations, telegraphists, etc. There is no limit of age or sex to any of these classes, provided the one golden rule is adhered to that its members shall in trade classes belong to the trade which they are learning. We also have, however, other classes suitable for women only—such, for instance, as cooking, art needlework, dress-cutting, etc., which are held in the young women's side of the Institute, and are confined to them alone.

There are, of course, musical classes of various kinds, elocution classes, and instruction on other subjects usually dealt with in educational institutions.

Another branch, and not an unimportant one, of the educational side of the Polytechnic is our day-school, which was the first of its kind in the kingdom. Here, for fees varying from $1\frac{1}{2}$ guineas to $2\frac{1}{2}$ guineas per term, parents can have their children instructed in the ordinary branches of education, and also in the theoretical and practical elementary knowledge of certain trades, so that a boy is able on leaving the school to go into a firm as an improver instead of as an apprentice, with the additional advantage of having spent two or three years at a school with its improving surroundings in place of having been pitchforked into a workshop at twelve or thirteen years of age, where his work at first would probably have been to drag a truck about the street or fetch the men's beer. It is a sight to do anyone good to visit the engineering or carpenter's shop and see some scores of these intelligent-looking lads learning the use of the lathe, plane, or other tools under the instruction and superintendence of practical mechanics.

There is also an advanced engineering school, where the fees are higher, and which aims at a somewhat more complete education—teaching civil engineering, surveying, levelling, higher mathematics, etc., and preparing boys for more responsible positions than those held by ordinary artisans.

In order to encourage excellence either in design, art, or mechanical work, an exhibition is held every year at Christmas, when many hundreds of the members of the Institute or classes exhibit the results of their skill, and the prizes are adjudged

by competent gentlemen representing various trades, who are always found ready to undertake the task. The Institute is always decorated by volunteer help for the occasion, and certain large rooms are put aside for the use of various sections, whose members add greatly to the amusement and interest of the show by entertainments or exhibitions of their own, the fees for which go towards the funds of the respective sections.

One great distinction between the Polytechnic and all other institutes preceding it, lies in the character of its teaching staff. Wherever a manual trade is to be taught, or technical instruction in such trade is to be given, we invariably try to get some first-class foreman mechanic instead of going to a merely theoretical professor. In our experience, not only are the results obtained by this method very much better, but there is of course no comparison in the cost, for the actual workman will be content almost with shillings where the professor will want his pounds. A foreman, moreover, working all day at his trade, is in thorough touch with the daily wants of apprentices and young workmen; he knows their language, their failings, and their requirements, and is consequently able, far better than a merely theoretical man could possibly be, to instruct them in what they want to learn. A highly-trained theoretical man may be necessary enough in one or two central places in London, but for the general instruction of our artisans I am convinced that a class taught by a competent foreman will beat almost any other.

So far for the educational work; now for the physical. A gymnasium is, of course, a *sine quâ non* both for young men and young women—indeed, it is doubtful if the latter do not need it most. Saturday afternoon rambles, Volunteer Corps, Medical Staff Corps, Artillery Corps, Harriers' Club, boxing, cycling, athletic clubs, and the like, are vigorously carried on, the Polytechnic Athletic Club playing, I believe, more teams than any other club in London, and the Cycling Club having obtained the proud position of premier club of England.

The above societies—and, indeed, all other clubs in the Institute—are volunteer organisations of the members themselves. They collect their own funds, expend them in their own way, elect their own officers, and manage their own affairs, their fixed rules being subject to the nominal approval of the governing body—which, however, has never had to use the veto.

The old boys of the day-school are bound to us by a special club, which plays its teams side by side with those of the other members, and throws itself into the ordinary Polytechnic life.

Another feature amongst our societies which is well worthy of imitation is the association of a number of students of particular classes for practising without expense the special studies which they prosecute. For instance, the members of the French classes formed themselves into a French society, which meets together for French conversation, dictation, writing, and other exercises, members taking it in turns to read aloud for the benefit of others, knowing that they themselves will receive similar assistance another evening. They will, further, arrange rambles in the summer and social evenings in the winter, to the great benefit of all concerned. This same system of mutual assistance is carried on by the members of the German, engineering, photographic, and other classes, and is a valuable adjunct to the paid instruction.

In addition to these scholastic and athletic societies, there are a number with more literary and social aims. For instance, there is a Parliamentary Debating Society, a Mutual Improvement Society, Chess and Draughts Club, Sick Club. There is a large refreshment-room, a large reading-room supplied with papers, magazines, etc., a circulating library, a room set apart for the secretaries of the various athletic clubs, and another for the members of the Council. This last-named body consists of 35 members, who are elected by the members of the various Polytechnic societies. It was felt when our members became so numerous that it was better to get representative members selected by the various sections of the Institute than to request the members to vote as a whole. The Council meet some of the governing body every month in an advisory capacity, and anything that has been going wrong or wants attention in any part or section of the Institute is then brought forward by the members, so that the governing body are more or less kept in touch with the desires and wishes of those whose interests they have at heart.

In the midst of all this, a certain amount of more distinctly religious work takes place. For instance, there is a Bible class, with an attendance of about 100 members, held on Thursday; another, held by myself, on Monday; a training class for Sunday-school teachers, at which the international lesson for the next Sunday is taken, and which is attended by 70 or 80 teachers, is held on Fridays; a young women's Bible class is held on Wednesday; and on Sunday two services for young men and young women respectively take place at 3.30, and a service for both sexes on Sunday evening. The expenses of these various classes are not large, but they form no charge on the general funds of the Institute, being provided from private sources. There is no religious test of any kind. We have,

I suppose, amongst us members of every possible shade of creed and no creed, and of varying political opinions.

One point seems to me in some danger of being overlooked in the newer polytechnics, viz., the social side. Our experience is that the sociability of members with each other affords a very fair barometer by which to measure the efficiency of all other sides of the work. If on going into the social rooms I find coldness, want of cordiality, mutual shyness, and incongruity, I can pretty well tell that the educational, athletic, and religious parts of the work are to some extent suffering. We Englishmen are not naturally demonstrative or cordial, and it would pay any polytechnic well to have two or three bright genial men with nothing to do but to mix up with the members and get them to know and like each other. Some of our members, feeling this, and desiring to do something useful with their leisure time, have formed themselves into a Social League, which takes up not only work such as I have referred to, but also social matters outside, and, in conjunction with the Christian Workers' Union, conducts entertainments, visits the sick, runs lodging and employment bureaux, and endeavours generally to make itself helpful. The Governing Body endeavours cordially to co-operate with the members in their desires, whether educational, athletic, or social.

There is a boathouse at Chiswick, with boats for our wet-bobs; a large recreation-ground of 30 acres at Merton, to which another at Harrow has now been added, for the use of cricket, football, and lawn-tennis members, north and south of the Thames. Special arrangements have been made with the Paddington Recreation Ground for the benefit of our cyclists, our day-school boys, two football teams, and the young women's lawn-tennis; and holiday trips for the benefit of members and their friends are run during the summer. These latter, independently of the actual holiday found and the recreation afforded, do a great deal to bring our members together and make them friendly and cordial. Saturday evenings all through the winter are devoted to self-supporting concerts, the outgoings and incomings about balancing each other. We invariably get a full house.

Amongst the more recent developments I may mention a Reception Bureau for young men and women coming from the country; a Labour Bureau run by the Social League; and a Co-operative Housing Scheme at Harrow, where members can obtain their freeholds by easy payments, and other advantages which I have not space to detail.

Such in brief is the Polytechnic. I only hope that those who seek to reproduce like results will not forget the means by which alone the Polytechnic Institute has grown to what it is. I should be sorry to see the spiritual side of man the one thing neglected. The fundamental lines which I should lay down, were I asked to do so, would be somewhat as follows:—

1. If you cannot do a thing well, leave it alone and admit nothing shoddy or second-rate.

2. Keep out patronage and toadyism as you would poison, and let whoever is at the head of affairs set the example of ignoring the artificial distinctions of class and occupation by mixing on cordial and equal terms with all the members.

3. Inasmuch as you have to deal with the young, keep the Institute lively. Let there be constant growth and improvement in the place, and to do this keep well in touch with your own members.

4. If you find yourself unable to follow any particular course desired by some, take the members into your confidence and explain to them the reason why. I have always found our members eminently reasonable when treated reasonably.

5. Do not attempt to attract members by lowering your standard. To do this is only the first step to ruin. English boys appreciate backbone, and admire the old man rather less than the donkey in Æsop's memorable fable.

6. The place is meant for the young, so do not let in the old. If you want to have young fellows between the ages of 16 and 26, you must, on the one hand, keep out very young boys, who would, innocently enough, make a playground of it, and who would thereby drive out young men, who would object to being disturbed by the "kids." On the other hand, middle-aged men and grey-heads, who will look up sourly if disturbed by a merry laugh or asked to put up with some inconvenience for the benefit of some function dear to young men's hearts, will equally drive out those whom you wish to attract. Then, of course, you must have a live man as secretary.

This, then, is the Regent Street Polytechnic. I hope and believe that it has only commenced its course of usefulness. I see many developments, such as housing its members, providing lodgings of a superior kind and at a cheap rate on the co-operative principle, obtaining labour news from its old members in all parts of the world for the guidance of intending emigrants, and the like, which as yet we have scarcely been able to touch. In days past its walls have been consecrated by earnest, faithful, and self-denying lives, desiring to give rather than to get; and with similar sentiments animating many of our present members, I look forward hopefully and thankfully to the years to come.

STEEL AND IRON.—V.

By William Henry Greenwood,
F.C.S., M.Inst.C.E., M.I.M.E., Assoc. Royal School of Mines.

[*Continued from p.* 205.]

CALCINATION OF IRON ORES (*continued*).

The details of construction and size of the kilns vary in different localities; thus on the Continent moderate-sized kilns are cylindrical, whilst the larger ones are elliptical or rectangular in horizontal section. With the circular masonry kilns, however, it is usually more difficult, without special devices, to regulate the temperature as required so as to prevent the centre from becoming too hot, and so clotting spathic and similar ores.

Kilns have also been built so as to be heated by fires at the sides of the kiln, when the flame and heated gases from such fires are conveyed through the materials charged into the kiln. In Sweden, magnetite and schistose hæmatite are roasted in circular kilns heated by the combustion of the waste gases from the blast-furnace.

In the Cleveland district, the kilns (Fig. 1) first introduced by Mr. Gjers are extensively employed; they are circular in section, and built of iron plates

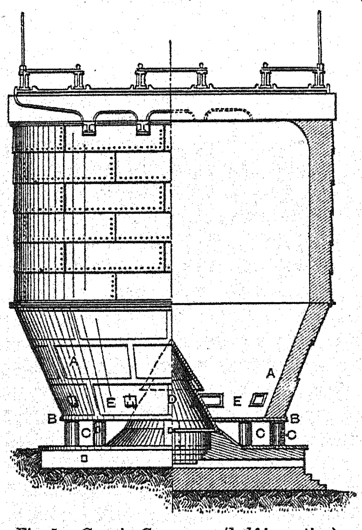


Fig. 1.—Gjer's Calciner (*half in section*).

lined with 14 inches of brickwork. Such kilns are about 33 feet in height and 24 feet in diameter at the widest part, having a capacity of about 8,000 cubic feet, holding, therefore, some 350 tons of ore and fuel; but they are also constructed of twice this capacity. Gjers' kiln resembles in appearance a low blast-furnace, with a conical lower portion A tapering towards the bottom. The body is carried upon a cast-iron ring B, which rests upon short cast-iron columns C, so as to leave a clear space between the bottom of the kiln and the ground of about 30 inches. In the centre of the kiln and resting upon the ground is fixed a cast-iron cone D with its apex upwards; this serves to direct outwards the descending roasted ore, which is then raked forward between the columns carrying the kiln, whilst fresh ore and small coal are constantly being added at the top, to replace the materials withdrawn at the bottom. Around the body of the kiln, and near the bottom of the same, are openings E usually closed by doors, but which can be opened for the admission of air as required for the process, and also for the introduction of the bars or other tools as may be necessary if the ore becomes softened or clotted from excess of heat.

A double roadway passes over the kilns, with a gangway between and outside the two roads, and the materials of the charge are brought in trucks along the tramway, and thence are introduced into the top of the kilns. Sufficient air for combustion is usually drawn in between the columns and around the cone D.

Weathering of Iron Ores is only necessary for such ores as contain pyrites or shale in considerable proportion; in which case, instead of directly calcining, or, in exceptional cases, after calcination, the ores are exposed in heaps for two or three months to the joint action of atmospheric air and moisture, whereby the sulphur is oxidised with the production of soluble sulphates which are dissolved out by the rains; but this method cannot be applied to calcareous ores, since the soluble ferrous and cuprous sulphates formed by the oxidation would be decomposed by the lime, with the formation of a sparingly soluble calcium sulphate, which would largely escape solution; and the deleterious elements, copper and sulphur, would thus remain in the ore, although in different states of combination from those in which they originally occurred. Also such calcareous ores cannot be subjected to any prolonged weathering *after* calcination, otherwise the ore breaks up and falls into powder, owing to the slacking of the lime during the lixiviation for the solution of the soluble sulphates, and so the ores become unfit for introduction into the blast-furnace.

REFRACTORY MATERIALS, CRUCIBLES, ETC.

The refractory materials used in the metallurgical treatment of iron and steel are fire-clays and a few natural rocks or minerals, either alone or suitably mixed with other ingredients, such as *lime, graphite* or *plumbago, burnt clay*, etc. The refractory materials are either moulded into bricks or crucibles of various forms, into pipes, tiles, tubes, etc., or are rammed in position upon furnace hearths, so as to

form the bottoms or linings of furnaces, as will be subsequently noticed.

Rocks can rarely be used alone for these purposes, owing to their want of homogeneity, their great tendency to crack when exposed to high temperatures, and their want of cohesion after being once broken up prior to their being moulded into the special shapes required in furnace construction.

Clays also are seldom used alone nor in their raw state, but require admixture with other ingredients, and some preliminary mechanical treatment, to adapt them to the requirements of practice, since raw, untempered clays, when used alone, invariably contract in volume, and crack when exposed to a high temperature, leaving thereby fissures and depressions which quickly lead to the destruction of the furnace in which they occur.

Fire-clays are essentially hydrated aluminous silicates, with small proportions of the carbonates of lime and magnesia, of iron as pyrites (FeS_2), smaller quantities of potash (K_2O), and soda (Na_2O), along with mechanically mixed silica (SiO_2) or sand, and with water in both the combined and hygroscopic form. Clays are generally refractory in proportion to their basic character—that is, to the alumina (Al_2O_3) which they contain—to their freedom from calcium carbonate ($CaCO_3$), iron pyrites (FeS_2), ferrous oxide (FeO), potash, and soda, any of which at high temperatures would quickly combine with the free silica (SiO_2) of the clay, with the formation of readily fusible vitreous silicates. The *plasticity of clays*, or their capacity to be moulded into any required form without loss of cohesion, is due to the chemically combined water which they contain, and, to some extent, upon the amount of alumina which enters into their composition; also the finer the particles, usually the more plastic is the clay.

Fire-clays vary from grey and pale brown to black in colour, have a greasy feel, and occur most largely in the Coal Measures of the carboniferous strata, in seams of from a few inches to 4 ft. in thickness; and less frequently fire-clays occur in various other geological formations. *Stourbridge fire-clay* contains about 63 per cent. of silica, 23·5 per cent. of alumina, with 10·5 per cent. of water and organic matter, and 1·5 per cent of ferrous oxide.

Lime is very refractory, and occurs native in the form of calcium carbonate, which, upon the application of heat, loses its carbon dioxide (CO_2) and becomes caustic, but it re-absorbs on exposure water and carbon dioxide and falls to powder, hence it can only be used in furnaces where a continuous, non-intermittent heat prevails; and owing to the facility with which lime and silica combine to form a fusible silicate, it is necessary to avoid contact of the two in any part of a furnace exposed to a white heat.

Dolomite is a highly basic magnesian limestone; it is highly refractory, but contracts by heating to whiteness to about one half of its original volume; hence, in using this substance it is necessary, before making it into bricks or otherwise applying it as a furnace lining, to well burn it, so as to expel carbon dioxide, and also to prevent, as far as possible, the great contraction just mentioned as arising when the material is strongly heated. Dolomite is now used (mixed with coal-tar as a cementing material) for the basic lining of the Bessemer converter in the so-called basic process for the production of steel.

Bauxite is a hydrated aluminous ferric oxide of variable composition, containing usually about 60 per cent. of alumina and only from 1 to 3 per cent. of silica, with 20 per cent of ferric oxide (Fe_2O_3) and from 15 to 20 per cent. of water, but some specimens contain much larger proportions of silica with less ferric oxide. It is a very refractory body, and affords an example of a substance containing some 20 per cent. of oxide of iron, but which is practically infusible. Bricks made of calcined bauxite, mixed with 6 or 8 per cent. of lime, are practically infusible and intensely hard.

Firestones, sandstones, granites, millstone-grit, serpentines, steatites, conglomerate, and other siliceous or quartzose rocks, are sometimes highly refractory, and stand considerable changes of temperature without cracking—hence such rocks are frequently employed for the hearth-stones of blast-furnaces, and for the boxes of the cementation furnace; but their use is limited, owing to the want of homogeneity and ofttimes also from the presence of metallic oxides in these rocks.

Ganister is a siliceous rock in which the silica is cemented together by argillaceous matter. The rock has usually sufficient cohesion to hold together after being simply rammed in the moist state around a wooden model having the form of the interior of the furnace; and in this manner the crucible steel-melting furnace and the ordinary Bessemer converter are lined with this material.

Siliceous Sand is an exceedingly refractory material, containing in some varieties as much as 97 per cent. of silica, the remainder consisting of a little lime, alumina, oxides of iron, and water. Such sand is used for mixing with fire-clays, etc., in the manufacture of fire-bricks, it constitutes also the mortar used in the setting of silica bricks, and is used in making the bottom or hearth of the Siemens Steel Melting Furnace. Sands less pure than the above are employed for making the pig-beds of blast furnaces, and by the moulder in making his moulds

for castings in cast-iron. Owing to the small cohesive quality in sands, though highly refractory, they are not available for most of the applications to which fire-bricks are applied.

Fire-bricks should always be set in a mortar of fire-clay, and not in the usual lime mortar; otherwise, at the intense heat to which they may afterwards be subjected, chemical union is possible between the

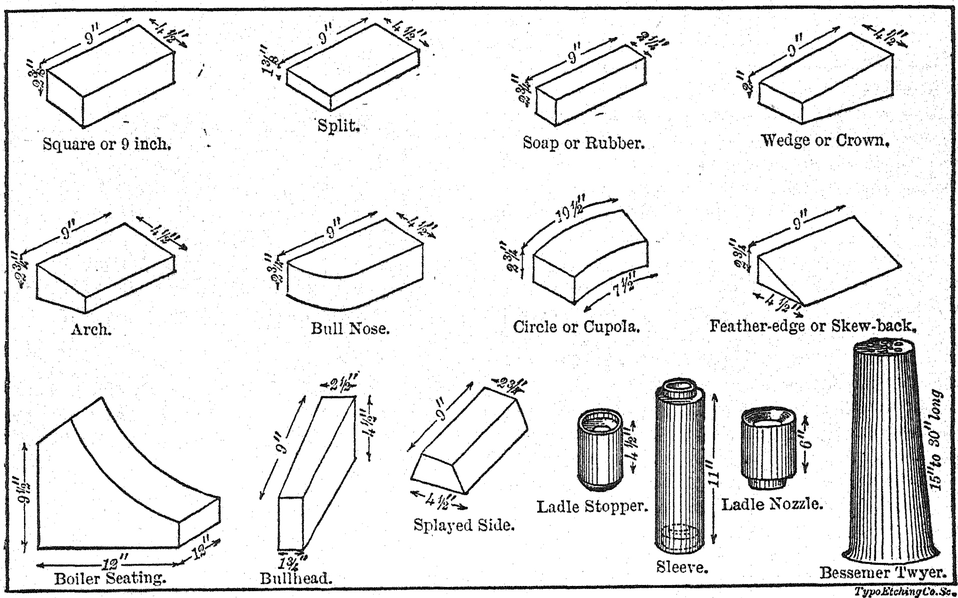


Fig. 2.—Common Forms of Fire-Bricks, etc.

Fire-bricks, when of good quality, are capable of resisting the highest furnace temperatures without softening, cracking, or suffering decomposition, and should also withstand great and sudden variations of temperature without suffering damage. For the production of a refractory slab, brick, quarry, tube, nozzle, etc, it is necessary that not only shall the materials be of the right description, but many precautions require to be observed, both during and after manufacture, to prevent them cracking and crumbling away. Thus, to prevent splitting and cracking during the drying of the bricks, or by subsequent rapid alternations of temperature in the furnace, the raw clay is first tempered or exposed for some time to the action of the atmosphere before it is moulded into bricks; and other materials also—such as previously *burnt* fire-clay, old bricks, graphite in powder, small coke, crushed quartz, or siliceous sand (as may be required for the particular purpose to which the bricks are to be applied)—are mixed with the clay. In the manufacture of fire-bricks the fire-clay is ground between rolls or under-edge stones, is kneaded with water, then moulded like ordinary bricks, and the bricks are afterwards thoroughly dried and baked in closed kilns.

free mechanically mixed silica of the clay, and the lime of the mortar, with the production of a fusible silicate, and consequent rapid destruction of the structure. Fire-bricks, like the Stourbridge, are usually pale brownish, reddish, or yellowish-grey in colour, often with dark spots, and when broken should show a compact close grain, free from cracks, and emit a clear ring when struck. Such bricks expand on heating from 32° to 212° F. about ·0005, would weigh about 7 lb. each, and they should not contain more than about 9·5 per cent. of their weight of water.

Besides the ordinary square brick of $9'' \times 4\frac{1}{2}'' \times 2\frac{1}{2}''$, fire-bricks are made for furnace construction in numerous special shapes and particularly named forms, amongst which are those shown in Fig. 2.

Silica Bricks, as the name implies, are composed largely of silica, and are made from a clay, stone, rock, or grit containing from 97 to 98 per cent. of silica with about 2 per cent. of aluminous and ferrous oxides with alkaline matters. Such grits are the Dinas Rock of South Wales and certain of the Millstone Grits in the neighbourhood of Sheffield. Silica bricks are of a light yellowish-brown colour, with a coarse, irregular, granular fracture, showing a

yellow matrix embedding fragments of quartz, which give to the fracture a rough, hackly appearance. These bricks are highly refractory, and are used most extensively for the roof, ports, and other parts of the Siemens Open Hearth Steel-melting and other furnaces, where the most intense white heat occurs. The bricks are very tender or brittle in comparison with ordinary bricks, and require considerable care in transport; they need to be kept from any lengthened exposure to rain or wet, and they cannot be set in a lime or clay mortar, but are laid with the smallest possible quantity of a paste of silica sand, or of silica cement and water. They cannot be used in contact with molten ferrous or other metallic oxides. Ordinary fire-bricks expand slightly on heating; but silica bricks contract very considerably during burning, and they also further contract on heating to high temperatures and expand on cooling, so that considerable care is necessary when strongly heating and cooling down furnaces in which these bricks are employed.

In the manufacture of these bricks, the rock is first broken up under edge-stones and mixed with milk of lime to the extent of about half a hundredweight of lime to a ton of the rock. The mixture is then pressed into moulds a little smaller than the finished bricks are required to be. The moulded brick possesses little cohesion, and is moved with care on to the drying-floors to be thoroughly dried, and afterwards the brick is burnt for about five or six days in either kilns or ovens.

PLUMBING.—V.

BY A PRACTICAL PLUMBER.

(*Continued from p.* 202.)

MITRE JOINTS, SETTING OUT ELBOWS, SOIL PIPE MAKING.

Mitre Joints (Fig. 60).—These, also termed elbow-joints, are not very frequently made by plumbers in lead pipe, especially soil pipe, for the obvious reason that the corners afford a lodging-place for filth and that from their shape they are liable to stoppage. Compare Fig. 60 with Fig. 47 and observe the difference. If the elbow were the other way about, that is, if it formed the first turn from the trap of a closet, the case would be slightly different, and the joint might be allowed, as the objection as to being liable to stoppage would not apply there any more than to a pipe branching in at the same angle. Even in this case, care would have to be taken that the mitreing was correctly done, so that no part of the pipe projected up as shown at A (Fig. 61), as anything in the shape of rag, string, etc., would catch there and cause trouble. There are two ways of making mitre joints: 1st, by joining two pieces of pipe both

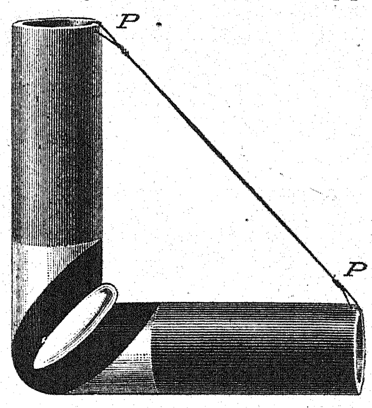


Fig. 60.

sawn to the required angle, as Fig. 62; 2nd, by sawing a V-shaped piece out of a length of pipe long enough to make the elbow (*see* Fig. 63). In this case the pipe is not sawn right asunder, but a

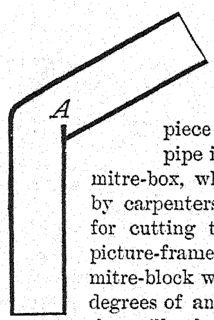


Fig. 61.

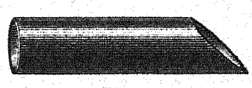


Fig. 62.

piece left to form the back. The pipe is usually sawn in a plumber's mitre-box, which is similar to that used by carpenters and picture-frame makers for cutting the angles for door-frames, picture-frames, etc.; Fig. 64 shows a mitre-block with mitres for three different degrees of angle cut in it. No. 1 is a cut that will, when the pipe is bent up, form an angle of 90° or a right angle. No. 2 cut will form an angle of 100°, and No. 3 of 110°; the straight cut A is for cutting pipe square across. The Nos. 2 and 3 will be found to be the angles

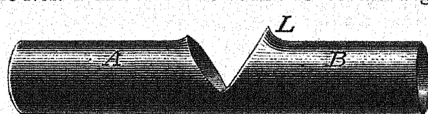


Fig. 63.

most frequently required, in fact a square bend or elbow such as Fig. 60 ought never to be used in plumbing practice if it can possibly be avoided. These elbows can be either wiped or copper-bit soldered, according to the purpose they are required for. If wiped a small lap is required; to get this lap the side B (Fig. 63), should be cut down a little farther than the other—you will notice that the

mitre-block provides for this—and dummied up at L as shown; the side A will then enter about ⅜ inch, which is amply sufficient, then gently pull

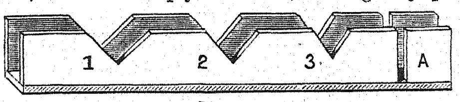


Fig. 64.

the two parts together; they can be held in position for wiping by a piece of wire fastened from P P (Fig. 60). They can be wiped at once all over if

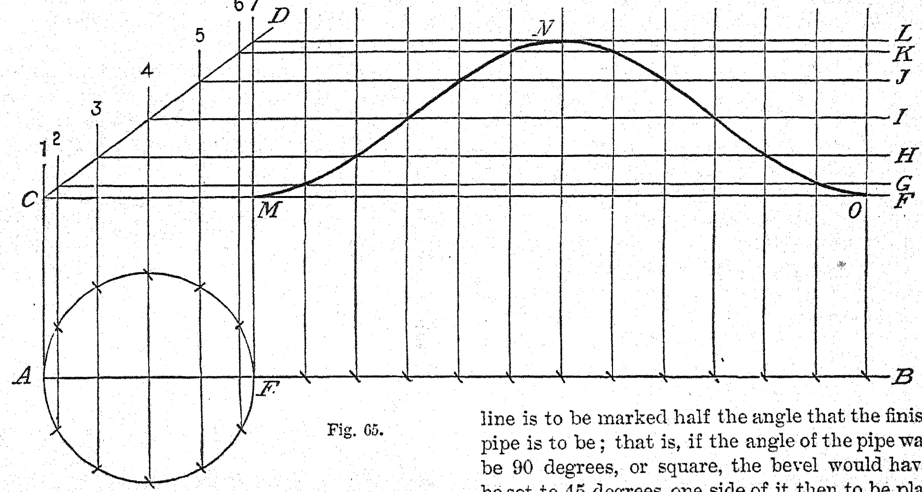


Fig. 65.

your mate understands moving it about right, but some wipe half at a time.

How to Set out an Elbow in the Flat.—Some-

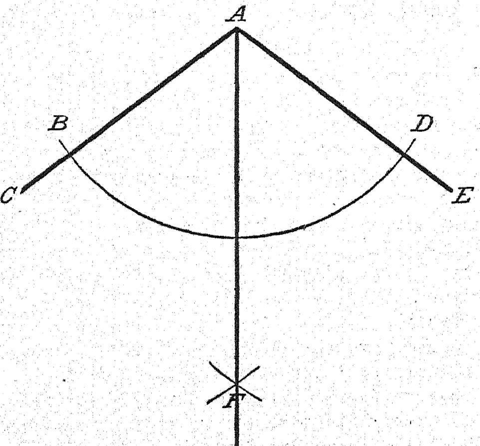


Fig. 66.

times the plumber is required to make elbows in other materials than lead and cut them out of the flat metal. By the method here given, an elbow of any degree of angle may be cut so that when turned round it will be as perfectly true a fit as if sawn in a mitre-block. Fig. 65 is the diagram. It is arrived at as follows:—Describe a circle the diameter of the pipe; draw the line A B any length longer than the circumference of the pipe, divide the circle into 12 parts, starting from A, and with the compasses in the same position, set off 12 parts along line A B, starting from E. Next erect the perpendicular lines 1 and 7. Next mark the diagonal line C D; this line is to be marked half the angle that the finished pipe is to be; that is, if the angle of the pipe was to be 90 degrees, or square, the bevel would have to be set to 45 degrees, one side of it then to be placed against line 7, and the line C D drawn across. Next draw the lines 2, 3, 4, 5, 6 parallel to 1 and 7, cutting the divisions of the circle as shown. Next, from each point of intersection of the lines 1, 2, 3, 4, 5, 6, and 7, with the diagonal line C D, draw lines F G H I J K L parallel to A B. Lastly, draw the curved line M N O from corner to corner, as shown, and the pattern is completed. I have spoken of setting the bevel to half the required angle of the finished pipe; this may perhaps puzzle some, though it is very simple. For an example, say you have taken the bevel of the required angle and marked it on a piece of paper, and that A C E (Fig. 66) represents it. From A as centre, with any radius less than the length of A C or A E, describe the arc B D, and from B and D as centres, with any radius greater than A B, describe arcs cutting each other in F; join A and F, and angle C A F is the angle to mark the bevel line for your pattern. These geometrical descriptions may seem a little obscure on reading them, but if worked out they are perfectly clear.

Soil Pipe Making.—Years ago the making up of soil pipe and traps formed a principal part of the

occupation of the plumber, and was always something to fall back upon in slack times; but of late years this has not been the case; improvements in

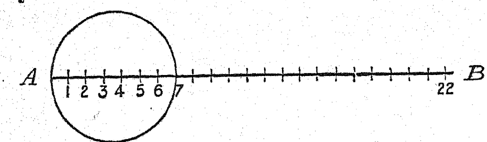


Fig. 67.

lead-working machinery now give us drawn soil pipes of reliable quality and true in gauge, and though of course a flaw is occasionally (but very rarely) found in them, the same can be said of hand-made pipes. This being the case, the plumber's occupation as far as regards the making of soil pipe is gone to a great extent. Yet as it is frequently necessary to make a piece or so, and as the knowledge of the process of making it is certainly requisite, I will describe it briefly.

Sizes of Soil Pipe.—Some difference of opinion exists among experts as to the best size for soil pipe, some advocating the use of a pipe as small as 3 inches; others would fix nothing smaller than a 4-inch and in many cases a 5- and 6-inch soil pipe. There is much to be said in favour of small-bore soil pipe; it is much more likely to be kept clean inside than a large-bore pipe. The 2-gallon flushes of water, which are all that the generosity of most water companies allow to cleanse a w.c., would exercise a far better scouring action on the sides of a 3-inch pipe than on a 4-inch. It is more convenient to fix, it is lighter, and less costly. The only argument against them is that they are liable to stop up; but I maintain not, at any rate not from the ordinary use of a closet. True, a brush or anything of that kind accidentally getting into the pipe might cause a stoppage; but, though we know strange things *do* get into closet pipes at times, yet it is the exception and not the rule. Mr. S. S. Hellyer, in his excellent work, "Dulce Domum," gives some thoroughly practical experiments with soil pipes of small bore (3-inch) fixed in his factory, and arranged to take the discharge of several closets used by forty or fifty persons daily. For some years these were in use without a sign of their stopping up, proving conclusively that there is very little to fear on that point. For myself I must admit that I am a partisan of the small-pipe system, and of my own accord would not fix any soil pipe larger than $4\frac{1}{2}$-inch; and it would, I think, be difficult to prove that this is not large enough for all purposes. I believe that this is so far admitted that there is more 4-inch pipe used than any other size.

Length of Pipes.—The shortest length advisable to make for stock is the width of the sheet of lead (7 feet), but 10- or even 12-feet lengths are required in large and high buildings to avoid making any more joints than is necessary.

Substance of Lead for Soil Pipes.—This should not be less than 7-lb. lead, that is lead weighing 7 lb. to the square foot super.; and if thicker it is all the better. But I am sorry to say that a lot of work has been put in much thinner than that in buildings of a speculative character. I have come across plenty of pipe of not more than 4-lb. substance.

Cutting Out.—The sheet of lead being unrolled (Fig. 68) on the floor of the workshop or on boards outside—*not* on stones or gravel, mark off A B each side to the length required, say, 10 feet; next along the lines A A and B B mark the size to cut the widths, the sizes for pipe of 3, $3\frac{1}{2}$, 4, $4\frac{1}{2}$, 5, and 6

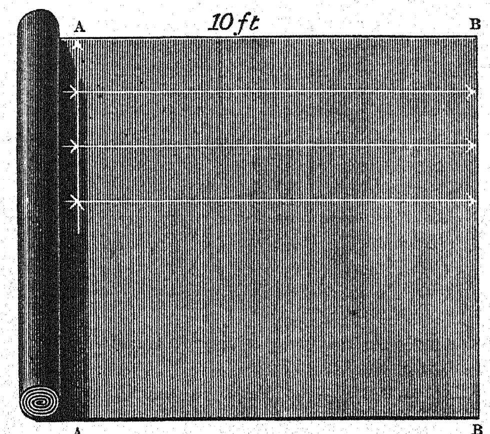


Fig. 68.

inches respectively are $9\frac{3}{4}$, $11\frac{1}{4}$, $12\frac{7}{8}$, $14\frac{1}{4}$, 16, and 19 inches. But the following simple method will enable you to get at the size required to cut the circumference of any size pipe, at any rate near enough for any size pipe that a plumber is likely to want to make. Describe a circle (Fig. 67) the same size as the required pipe is to be. Draw a diameter to it and produce it somewhat more than two diameters beyond the edge of the circle as shown, A B, divide the diameter of the circle into 7 parts and set off 15 more of these parts along the line towards B: the length from A to the end of 22nd space from A is the size required. The same result is arrived at by multiplying the diameter of the required pipe by 3 and adding $\frac{1}{7}$ of the diameter. Example: a 7-inch pipe $7 \times 3 = 21 + 1 = 22$. If you are working single-handed, you must use a long straight-edge and make the lines with a scriber. I prefer, however,

to use a chalk line for marking out long straight lines: it is used as follows. Well chalk a sufficient length of line, get your mate or someone to hold it firmly down at one end, letting it run true through the marking points, stretch it tightly and hold it down your end; pull it up a few inches, and let it smartly down on the lead, when it will leave a plain mark easy to be seen; the line must be lifted vertically or it will not mark a true line. The cutting is not done in the same manner as with most other sheet metals, viz., by using shears or hand snips, but with a knife. There are two kinds of knives used in cutting out lead: one, called a drawknife, consists of a stout blade about 6 inches long, straight-shaped, let into a handle from 2 feet 6 inches to 3 feet long; in the blade, about 4 inches from the point, is a hole, through which is passed a stout cord. The

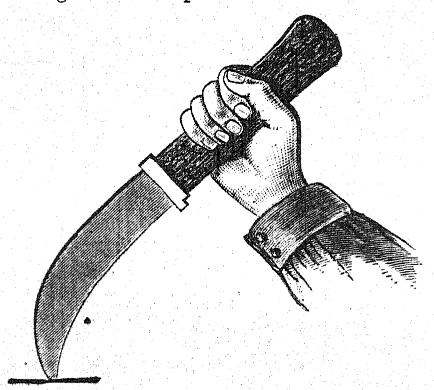


Fig. 69.

plumber takes the knife and guides it straight and puts the pressure on, and his mate pulls the rope. The other is an ordinary stout pocket knife slightly hooked at the point; in cutting it is held at the angle shown at Fig. 69, or even a little lower, and care must be taken not to jerk the knife along but to cut with a steady forward movement. If the points of these knives are wetted, they will cut all the easier for it. After cutting the lines, "snick" the ends with the knife, and you can then pull the pieces off or roll them up, which is the best way. Unless you are sure of cutting very true, it is best to allow at least $\frac{1}{2}$ inch more than the sizes given above, to allow for trimming after the lead has been "dressed" flat. This is done with the dressers before mentioned, taking great care to dress it free from all bumps and dents; before dressing brush both sides of the lead and also see that nothing is on the bench that would injure the lead, such as a tin-tack, nail, or fragment of metal. Next trim it to the absolutely correct sizes, plus $\frac{1}{8}$, which you will take off again in shaving the edges, which is sure to be necessary, however true you may think that the lines have been cut. The best way to do this is to fix a board on the bench so that the lead is set up about $\frac{1}{2}$ or $\frac{3}{4}$ inch off the bench, then secure the lead to the board and plane the edges with

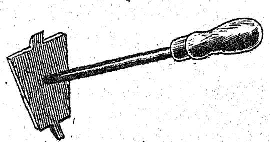


Fig. 70.

a jack plane, taking care not to set the plane iron too deep; trim up both edges in this way, square off the ends, and the lead is ready for bending, which is the next process. This is accomplished by pulling round on a mandrel, and takes two or more to do it if the lengths are over 7 feet. The mandrel should be the exact size of the inside measure of the pipe, if anything a trifle larger would be better, for it would not matter if the lead did not come right round within $\frac{1}{4}$ or even $\frac{1}{2}$ inch, as it could easily be pulled together, but if there were more lead than would go round, it would be awkward. The method of bending is as follows. The mandrel is placed on the lead, taking care to have it parallel with it, the plumber and his mate pull the back part of the lead round on to the mandrel, lightly dress the edge down, and then pull right round and finish dressing the two edges. Do not strike them hard or you will throw the edges out of truth again. Having done this, the mandrel can be withdrawn and the pipe is then ready for soiling, which for a fine soldered joint should be 1 inch each side.

Shaving and Soldering the Pipe.—The shaving in this case is done with a gauge hook (Fig. 70), which shaves the pipe to a uniform size all along; "touch" the shaved parts, and let your mate press and hold the edges of the pipe firmly together, whilst with a copper bit and stick of fine solder you tack it in several places along the seam (about every foot will do), and be careful to keep the two sides level or the seam will look very uneven when finished. Now sprinkle some powdered resin along the seam and go right along it; let the copper bit be well heated, and let it be a good-sized one, thoroughly well tinned and free from dirt. The pipe will now be thoroughly warmed and ready for the finishing touch, which is done by re-heating the iron and floating the solder smoothly from end to end. A seam properly soldered in this way is as strong as anything need be, and is the most expeditious way of soldering them. The pipes must be carefully examined to see that no solder has run through and formed

spurs on the inside; if there are, they must be cut off or melted down.

Drawn Seams.—These are made with plumbers' solder and iron, and are much more difficult to make. The difference in preparation is that the soiling is much wider—2 inches each side, the shaving should also be wider, ½ inch each side, "Touch" the seam, and with a very hot copper bit

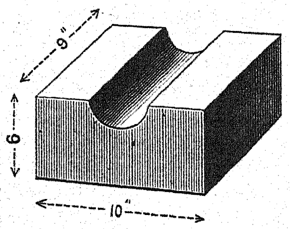


Fig. 71.

tack the pipe at intervals along it, the labourer holding it close as in the previous case, but instead of using fine solder use a stick of thick lead (7 or 8 lb.) ⅜ or ½ inch wide, shaved clean; dip the end in powdered resin as you use it: this is called burning it together, and it is more likely to keep the pipe from coming open as you solder the seam than if fine solder were used.

In "drawing" the seams you will require the assistance of a labourer, to follow up the seam and cool it with a stream of water at every few inches as you proceed.

Commence by pouring on the metal at one end till you get up the heat, then run the metal along 10 or 12 inches, and draw the hot iron along each side, this will leave a body of solder on the seam while the remainder runs off at the sides, the labourer, with a piece of wood, pushing off any little superfluities of metal that may cling to the sides; you must then keep right on in the same manner till the seam is finished. The seams can also be wiped by splashing or pouring the metal on, and using an iron or a blow lamp, and following up with the cloth. For convenience in performing all these soldering operations, a pair of soil-pipe blocks (Fig. 71) will be necessary. They are simply blocks of wood of about the sizes shown in the sketch with a hollow in them cut to the sweep of the pipe, by their use the pipe is kept steady whilst soiling, shaving, and soldering.

It is not absolutely necessary to have a pair of blocks for each size pipe, the 3-inch blocks, if made slightly full, will then do for 3-inch and 3½-inch pipe; the same for 4-inch and 4½-inch, and so on. To still further lessen the number of blocks, they can be grooved both top and bottom.

COTTON SPINNING.—V.

By Henry Riddell, M.E.

[*Continued from p. 209.*]

OPENING (*continued*).

Opening.—After passing through the bale breaking and mixing processes the cotton is ready for the opening—a process which is intended to loosen the fibre still further, and remove the sand and dirt with which it is mixed. In the early days of the cotton trade in England this operation was manual, the cotton being pulled apart by hand, and afterwards spread upon a grated floor and beaten with withes or rods of *willow*, the work being known as "batting," or "willowing." It was exceedingly expensive in labour, although in many ways a most successful process in treatment of the fibre as far as avoiding damage was concerned. There was also a constant liability of carrying away a quantity of dust with the open fibre.

As a means of reducing largely the cost of the cleaning and opening, the machine known as the "Willow" was introduced, taking its name from

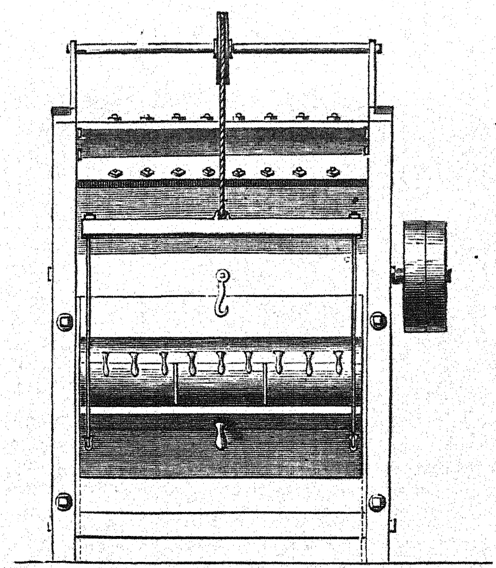


Fig. 10.—The Square-framed Willow. (*Front View with Door Open.*)

the process employed earlier, which had been so called from the wood used for the rods.

The use of the "willow" is almost extinct, except in the Oldham district, where a number are yet employed. It was a very great advance on the beating upon the floor, but in most cases has had to yield its place to the more perfectly automatic machinery now used. Even in the Oldham

district the "willow" has its employment mostly in the manufacture of yarn from waste, and it is doubtful if for any other purpose its use is ever advantageous. As it is, however, still in use, a

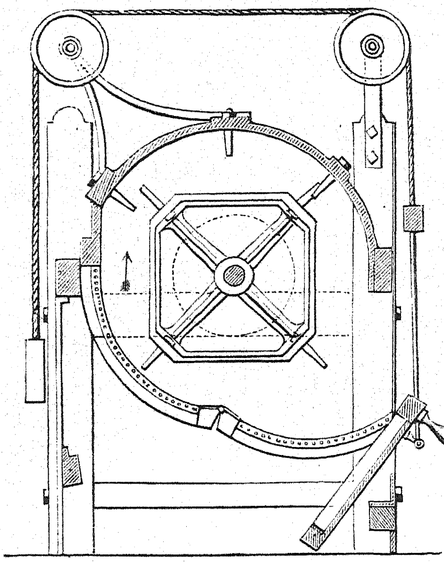


Fig. 11.—The Square-framed Willow. (*Side Section.*)

short description may be given. In its earlier form (Figs. 10 and 11) the "willow" consisted essentially of a cylinder, carrying at intervals upon its surface rows of strong teeth or spikes, and covered upon its upper half circumference by a casing furnished internally with spikes similar to those upon the surface of the cylinder, while the casing of the lower half is constructed of perforated metal or wire. This lower cover is hinged at one end so that it can be raised or lowered by means of a chain passing over a pulley. The cylinder is carried upon bearings which are parts of the framework, and is driven at a high rate of speed. In operation, the grating is lowered, and being covered with a quantity of cotton is returned to position and the machine started. The cylinder teeth lay hold upon the cotton, and by the centrifugal action due to the surface speed the cotton lumps are thrown against the spikes of the upper casing, and by repetition of this action are opened and the fibre freed from dust and dirt, which drop through the perforated lower guard. In a very short time the work is completed as far as the cleaning is concerned, and the grating being again lowered the cotton is removed. In this machine there was a rough action upon the cotton, by no means improving its spinning qualities, and there was no certainty that neither more nor less than the proper amount of work would be put upon the fibre, as everything depended upon the judgment of the attendant. In a later form of the "willow" this latter defect was lessened by adding a feed apron, and a travelling lattice at the delivery end, by which the cleaned cotton could be delivered at a convenient distance.

Modern Machines.— Of cotton opening and cleansing machines of more modern construction there are two great divisions, which are representative of distinct ideas, and employ very different methods to effect the same result. One example of each division will serve to show the difference in treatment and sufficiently exemplify present practice, as the other machines employed are not so different in principle or construction as to require separate description.

Crighton Opener.—Of the first class the most characteristic machine is the Crighton Opener, which is so largely in use and so much appreciated, especially for the American short-fibred cottons.

The illustration (Fig. 12) shows the essential parts of the machine. This opener consists of an upright shaft revolving in a conical cage, and carrying a series of cast-iron circular discs. The cage stands, with its smaller end downwards, inside a cylindrical casing, and is formed in a series of steps, gradually increasing in diameter from the bottom to the top. The bottom is a dish-shaped metal casting with corrugated inner surface, and rises about one-third the total height of the cage, open to the feed tube at one side; beneath this dish is carried the footstep which bears the upright shaft, while across the top of the case is fixed a plate, forming a cover and bearing a bridge in which is fitted the long journal carrying the upper end of the shaft. The discs upon this upright have, bolted to their outer edges, steel beater blades, which are the working tools of the machine, and are fixed at various angles as plainly indicated in the sketch. From the dish-shaped bottom casting to the top of the conical cage the sides are perforated into a series of grids of a peculiar shape, designed to allow of the free passage of dirt without losing by the same path any of the fibre. In order to accomplish this, the steps previously mentioned are formed into little niches, as shown in section, and open at the bottom of each step to allow of the dust falling freely. Between the little circular niches small slots are left, shaped at the sides with a slope narrowing the opening towards the outside.

During the passage of a beater blade across the

cotton at any point, the speed of the movement causes a sudden local compression of the air, which if not relieved might drive the cotton downwards with the dust, but this tendency is removed by the immediate outlet allowed by the slots.

The feeding is through a tube which slopes downwards to the bottom of the casing, but turns into the cage at an easy curve to avoid the jamming which might otherwise take place there.

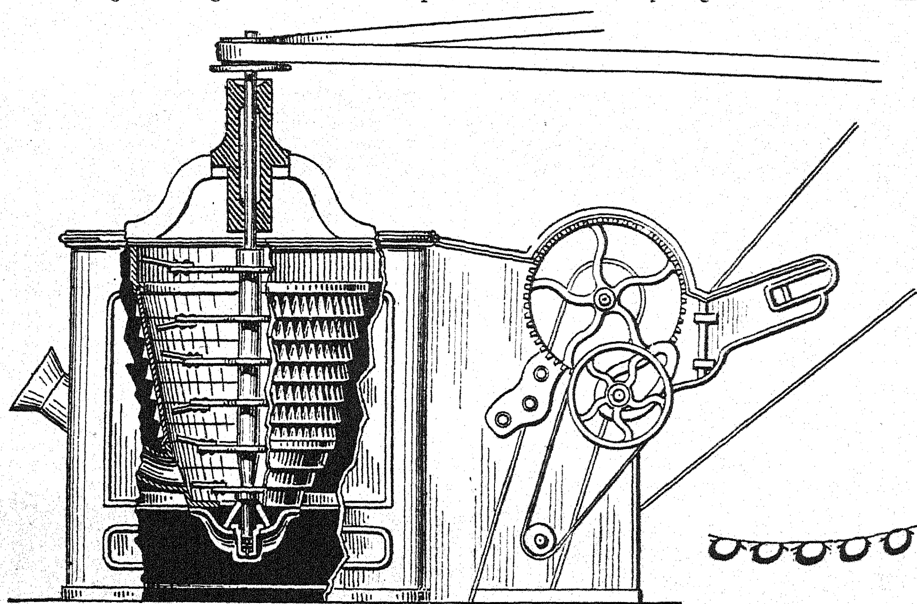


Fig. 12.

The motion of the cotton into and through the machine is obtained by means of an air current due to the suction of two fans, one of which, placed so as to exhaust the air below the dish, may be called the feed fan, its duty ending with the arrival of the cotton within the cage; while the other, outside the machine, causes the upward current which gently lifts the opening fibre in the cage and finally lands it at the delivery, where a lattice is ready to dispose of it. The action of this machine upon the cotton is very effective, the gradually opening cotton being lifted in the cage only to meet with quicker and more energetic treatment from the beater blades, until it reaches the top well opened and cleansed.

One advantage of this type of machine is that once the dirt is shaken from the cotton, it is finally got rid of, there being no danger of its falling among the other cotton and remaining there.

The feeding of this machine can be done by a lattice, or other feed arrangement if desired, and it is when the mechanical feed is used and connected to the opener by "air trunks" that the full advantage of the fan action described is found.

Air Trunks.—As these contrivances are in constant use in the opening rooms of a cotton mill, it is necessary to describe them, and give such particulars as are required for the understanding of their construction and working.

There are many different varieties of these air trunks, but the principle common to all is the use of air currents for carrying cotton in its loosened condition through a tube from one machine to another, even when separated by a considerable distance or in different rooms. Their use is looked upon as greatly lessening the danger from fire, as it enables the most dangerous work to be done in isolated departments, while the cleaner and less risky operations can be performed where most convenient.

At the same time these tubes are useful in two other important ways—as saving expense in handling, and as providing a means of removing part of the dust and heavy impurities from the pulled fibre, thus lessening considerably the duty thrown upon the opener. In Fig. 13 are sketched two forms of this apparatus—in diagram only, as the actual construction varies very much.

The lower of the two forms figured represents in its principal details the greater number of those in use,

at least in modern mills. A portion of the tube is formed as shown in sections, square-bottomed, and having at short intervals plates fixed, extending from the bottom about half-way towards the top of the tube, and often inclined slightly against the direction of motion of the cotton, which rolls over them with the air current. Into the spaces thus formed much of the dirt drops, and is periodically removed through doors provided for the purpose.

Howard & Bullough have introduced doors in the top of the air trunks manufactured by them, and have fixed the cell plates to the bottom doors so as to descend with them, thus providing very great facilities for cleaning and for freeing the tubes in case of an accidental stoppage by the balling of the cotton.

The same firm provide a stop motion which, when the machine fed from the trunk stops work, arrests the feed to the air trunk, no matter how distant that may be. This is undoubtedly a useful improvement, as preventing that jamming in the tube which is often otherwise unavoidable.

Messrs. Platt have invented an automatic method of removing the dirt from the cells, which is shown in the upper sketch in the figure, and which ought to be very advantageous if the mechanism can be relied upon in its somewhat trying position. In this form the firm mentioned have added a lower chamber into which the doors in the bottom of the air trunk open directly, being balanced so as to swing automatically when a certain weight of dirt has collected upon their upper surfaces. In this chamber an endless conveyer is provided, upon which the dirt drops and is carried to a down shaft at one end, while scraping blades are fixed so as to clear the bottom of the chamber of any droppings which have shaken through or alongside of the traveller, sweeping them to a second down shaft at the opposite end.

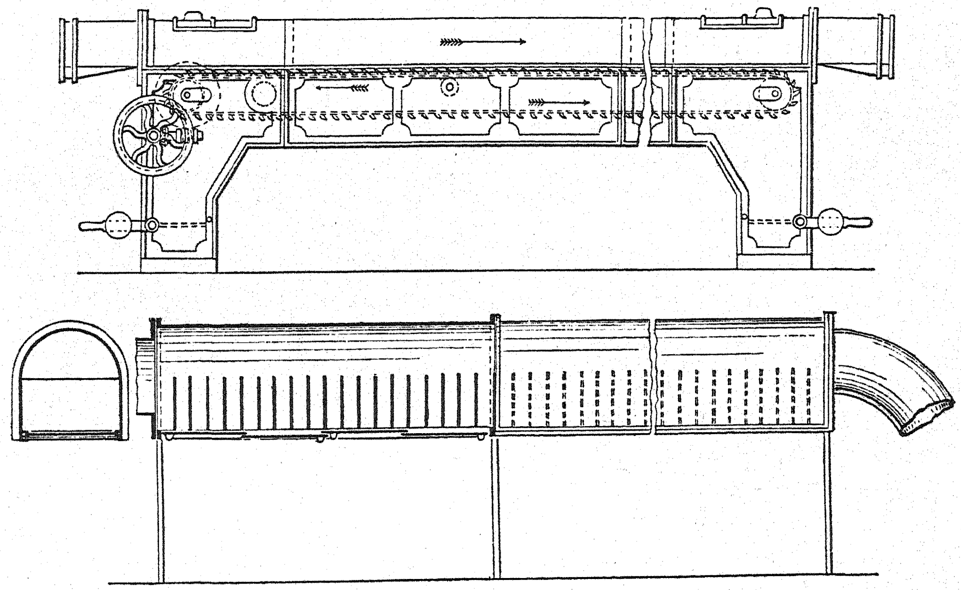


Fig. 13.

In all pneumatic tubes the regulation of the air is most important—if the current be too heavy the impurities have no time to settle, and if too light the tube chokes. The best regulation allows the cotton to waft gently with the air current over the top of the dirt cells.

Openers belonging to the second of the two great classes mentioned may be described as *modified willows.* In machines of this class the constant feature is the large toothed or pinned cylinder, acting upon the cotton as in the willow. The teeth are not intended to tear the cotton, but to throw it violently against the corresponding projections of the casing; hence they are not closely placed, but are rather thinly set upon the cylinder surface, and are large so as to act by a shaking blow, and not at all in the manner of the card clothing to be described later.

Porcupines.—As belonging to the modified willow variety of openers the porcupines are much used, especially as feeders to machines of another class,

such as the vertical beaters, to which the Crighton opener belongs. The name is from a fancied resemblance due to the erect spikes in the cylinder surfaces. As made by Dobson & Barlow (Fig. 14) the porcupine has a lattice feed, leading to one or two pairs of coarsely fluted rollers which present the cotton to a cylinder $13\frac{1}{2}$ inches in diameter, made with hardened steel teeth, riveted to circular rings. It may deliver direct to another opener, or upon a lattice or into a pneumatic tube.

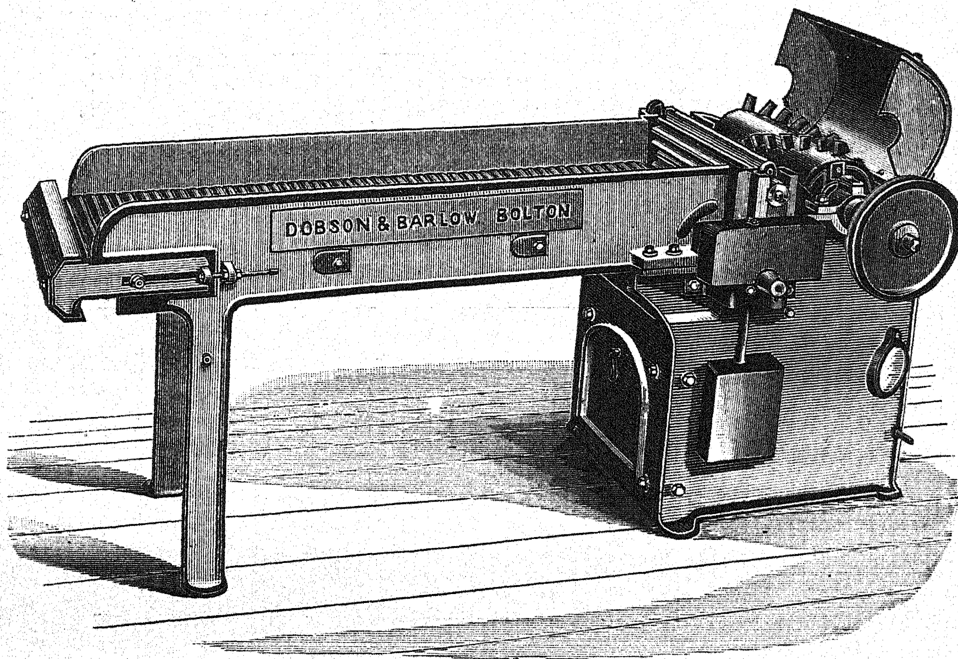


Fig. 14.

A large cylinder of the modified willow type is more commonly used, combined in the same machine with an opener of the scutcher type, as made amongst others by Dobson & Barlow and Lord Brothers.

Fig. 15 represents the machine as made by Dobson & Barlow, showing at the feed end the lattice traveller, and at the delivery end the lap-forming arrangement. In this machine there are four points which require a special examination, as they have not been previously dealt with—they are the scutcher-beater, the dust cages, the lap-forming arrangement, and the pedal levers of what is known as the "piano feed." All these devices belong essentially to the scutcher rather than to the opener, but as they constantly recur in the different modern makes of opener, they may be described now.

Scutcher Beater.—This is constructed upon forged centres as shown in section, the arms being forged with their bosses; these centres vary in number according to the width of the beater. The arms are most often two in number upon each centre, but three are frequently used, and there is much difference of opinion as to which number is most suitable. The two-armed variety is easier to balance properly, and an even balance when running is essential to good work; yet three-armed beaters work satisfactorily when well made. When three arms are used, as is often the case in machines made by makers of the greatest experience, the speed of rotation does not require to be so high to give an equal number of blows per minute, and therefore the blow is softer, not so sharply given. Some cotton seems to suit better with this than with the sharp stroke of the two-bladed beater, although the working of the latter is favoured by very high authority.

Across palms provided upon the arms are fastened the steel case-hardened blades, shaped so as to present an edge or angle to the cotton, and to touch it with the edge only, not to rub with the body of the blade. The speed of the two-winged beater is from 1,000 to 1,500 revolutions per minute, and is varied according to the cotton worked.

The beaters are sheeted above by an air-tight case, and have a series of graduated grids or grate bars below to allow of the escape of dirt and waste fibre.

than that of a generating line of the cone, as at $P_4 P_4$, the curve of section has two infinite branches and is called a hyperbola.

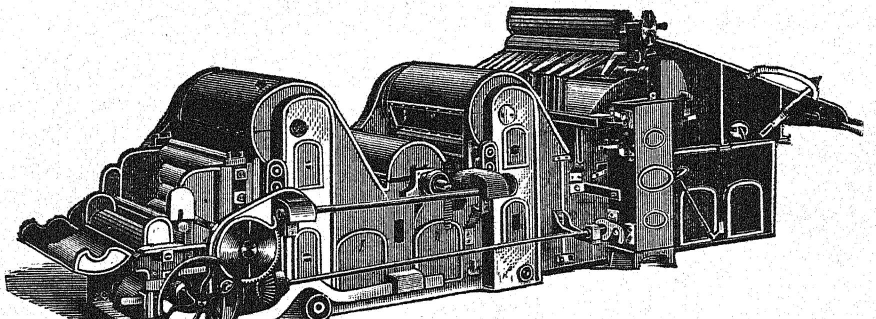


Fig. 15.

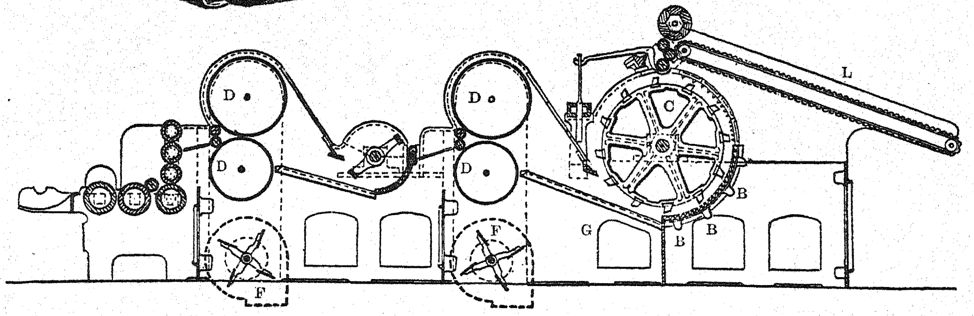


Fig. 16.

PROJECTION.—V.

[*Continued from p.* 213.]

SECTIONS OF SOLIDS BY PLANES (*continued*).

In pure geometry a cone means what we might call a double cone (*see* Fig. 52), *i.e.* the complete cone is the locus of a straight line passing through the vertex and also through a point on a curve the plane of which does not contain the vertex. The straight lines are supposed to extend indefinitely in both directions. This curve may be of any shape whatever, but if a cone is spoken of without any qualification, a right circular cone is usually meant. The "conic sections" are the curves obtained by making plane sections of a right circular cone. If the plane $P_1 P_1$ be perpendicular to the axis of the cone, the section is a circle. If the plane be parallel to one of the straight lines on the cone, as $P_2 P_2$, the section is a parabola. Should the plane of section lie within the acute angle $P_1 O P_2$, the section is an ellipse. Should the plane of section pass through the axis, the section is a pair of straight lines. Should the inclination of the section plane to the axis be less

The student will probably have learnt from plane geometry methods of drawing these curves. Having given sufficient elements to determine them, we will show how to determine the lengths of the axis, the centre, the foci, and the directrix of the conic section made by a given plane.

Let V be the vertex of the cone and P P the plane of section. Fig. 53 shows the position of the plane to give an ellipse, Fig. 55 to give a hyperbola. Let f_1 and f_2 be the centres of two spheres inscribed in the cone and touching the plane P P. Let $e_1 e_1$ and $e_2 e_2$ be the points of contact of the circles which represent the spheres in elevation with the two straight lines $v u$ and $v w$ forming the elevation of the cone. Let $e_1 e_1$ produced cut P P in d_1 and $e_2 e_2$ produced cut P P in d_2. Let P P cut $v w$ and $v u$ in a_1 and a_2 respectively. Let c be the middle point of $a_1 a_2$. Draw a straight line parallel to P P to represent the axis of the conic section, and from a_1, a_2, f_1, f_2, and c project on this line A_1, A_2, F_1, F_2, and C. A_1 and A_2 are the vertices of the curve, F_1 and F_2 the foci, and C the centre. From d_1 and d_2 project the lines $D_1 D_1$ and $D_2 D_2$; these are the directrices. In the case of the parabola (Fig. 54)

the points C, F_2, and A_2 and the line D_2 D_2 are at an infinite distance.

The length of the minor axis of the ellipse may

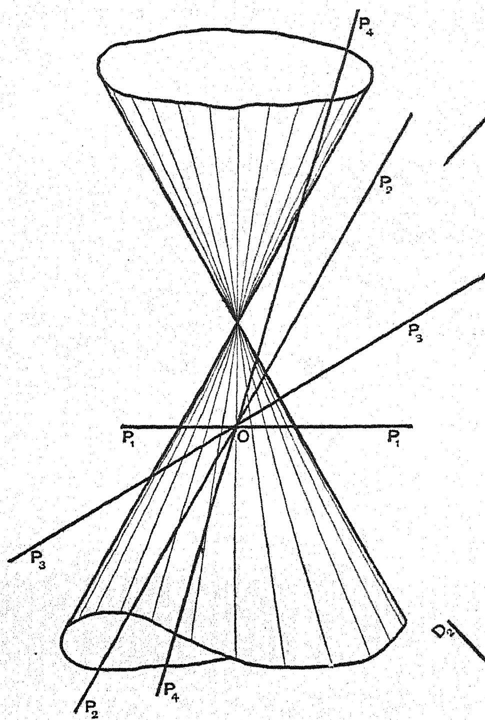


Fig. 52.

be found as follows: Through c draw $g\,g$ at right angles to the axis $v f_2$ of the cone, cutting it in h, and cutting $v\,u$ and $v\,w$ in g and g. On $g\,g$ draw a semicircle, and at c erect the ordinate $c\,k$ to the semicircle. $c\,k$ is equal to the required length of the semi-minor axis C B of the ellipse.

The asymptotes of the hyperbola may be drawn as follows. Through v draw v Q parallel to P P. Take any line $l\,m\,l$ at right angles to the axis of the cone, cutting the axis in m, the sides $v\,u$ and $v\,w$ in l, l, and v Q in n. On $l\,l$ draw a semicircle and draw the ordinate $n\,r$. Draw $n\,k_1$ and $n\,k_2$ at right angles to $v\,n$ and equal to $n\,r$. The lines $v\,k_1$ and $v\,k_2$ are parallel to the asymptotes CY_1 and CY_2 of the hyperbola.

SOLID OF REVOLUTION.

If any plane curve revolve about any axis in its plane, it will trace out a surface of revolution. A cone, a cylinder, and a sphere may each be regarded as a surface of revolution.

If a closed curve revolve about an axis in its

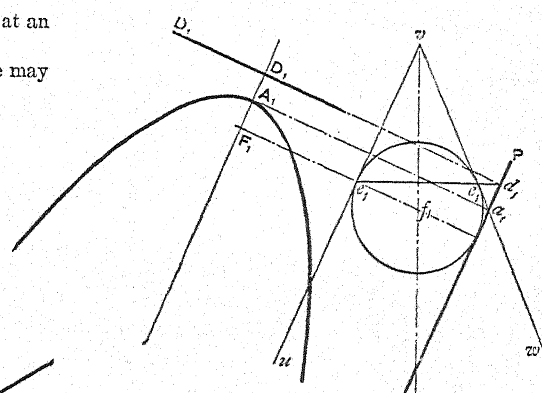


Fig. 54.

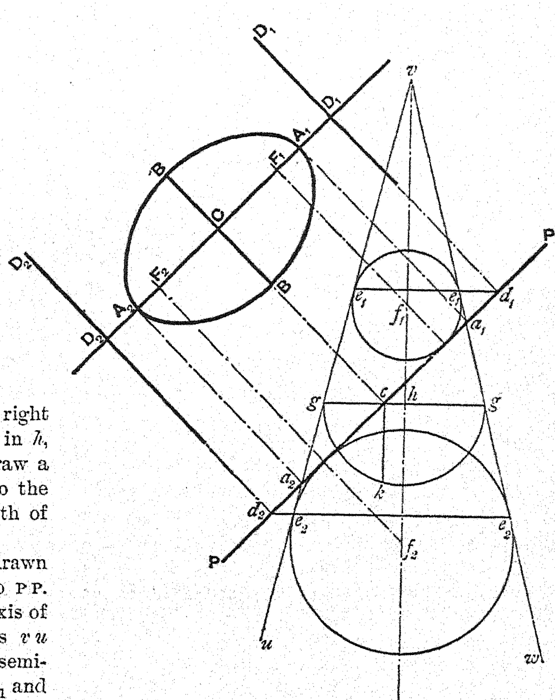


Fig. 53.

plane, but not intersecting the curve, the surface of revolution is called an annulus.

The following problem will serve as an example of the method to be adopted when dealing with plane sections of surfaces of revolution.

An annulus of circular section resting on the H.P. is cut by a plane inclined to the H.P. and at right angles to the V.P. Draw plan of the lower

part of the solid and show the true shape of the section.

Fig. 56 shows plan and elevation of the annulus and the elevation Q Q of the plane of section, the circles A A A and B B B being the section by a plane parallel to the V.P. and passing through the centre of the annulus. The section of the annulus by a horizontal plane will be a pair of concentric circles.

Divide the circle A A A into a number of equal parts $a'_1, a'_2, a'_3, \ldots$ (say 12) beginning at the top. Through a'_1 draw a line $a'_1 c'_1 b'_1$ parallel to X Y; and from a'_1 drop a projector $a'_1 a_1$ on to the line M N, parallel to X Y and passing through O, the centre of the annulus. With centre O and radius O a_1 draw a circle $a_1 c_1 b_1$. $a_1 c_1 b_1$ and $a'_1 c'_1 b'_1$ are plan and elevation respectively of a circle lying on the surface of the annulus. Let p'_1 be the intersection of $a'_1 b'_1$ and Q Q; from p'_1 draw a projector $p'_1 p_1$ to $a_1 c_1 b_1$. The point $p_1 p'_1$ lies on the curve of intersection of the annulus and plane Q Q.

If this construction be repeated for the points $a_2, a_3 \ldots$ a number of points $p_2, p_3 \ldots$ will be obtained, which being joined by a fair curve will give the plan of the section required.

The true shape of the section is got by taking a new X Y parallel to Q Q, or by taking $M_1 N_1$ parallel to Q Q and marking off from $M_1 N_1$ along the projectors the corresponding distances from M N.

The plan is evidently symmetrical about M N. In Fig. 56 only half the plan and half the true shape of the section have been drawn. The construction lines are fully drawn for 12 points, and partly drawn for other 12 points, in all 24 points on the half plan have been determined.

The student may work out the example (Fig. 56) a number of times, varying the position of the cutting plane Q Q. In the position shown in the figure, *i.e.*, Q Q cutting only one of the circles A A A and B B B of the elevation, the complete curve of intersection is one closed curve. If Q Q cuts both circles A A A and B B B the complete curve of inter-

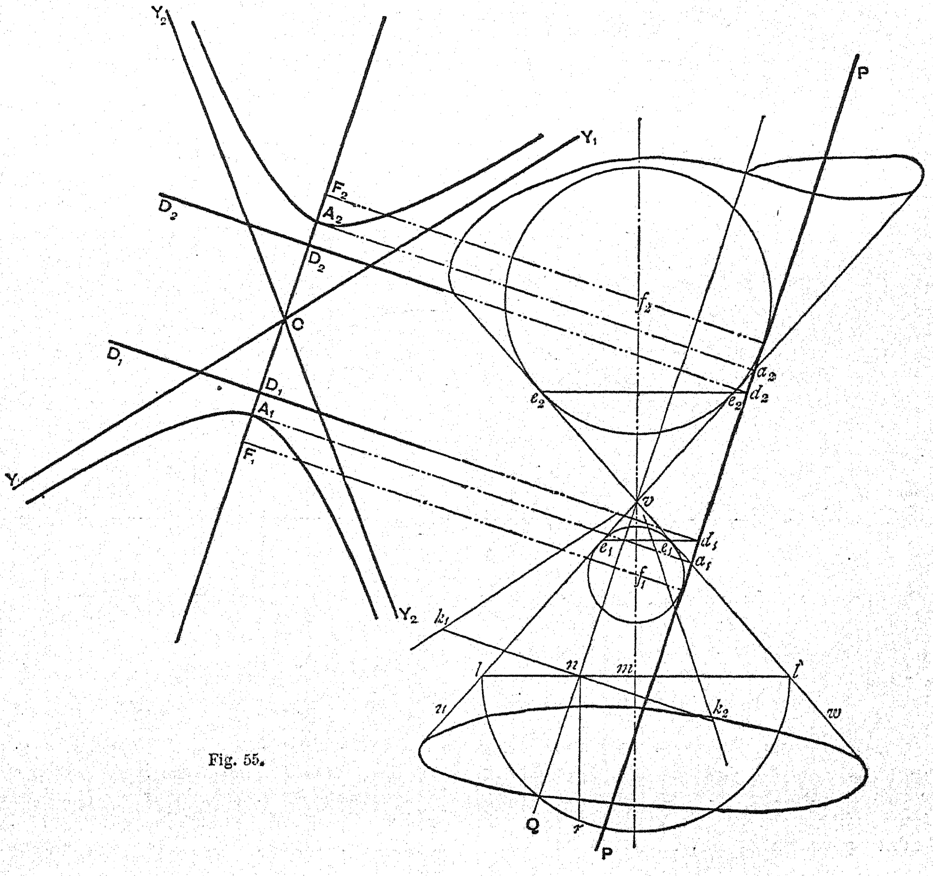


Fig. 55.

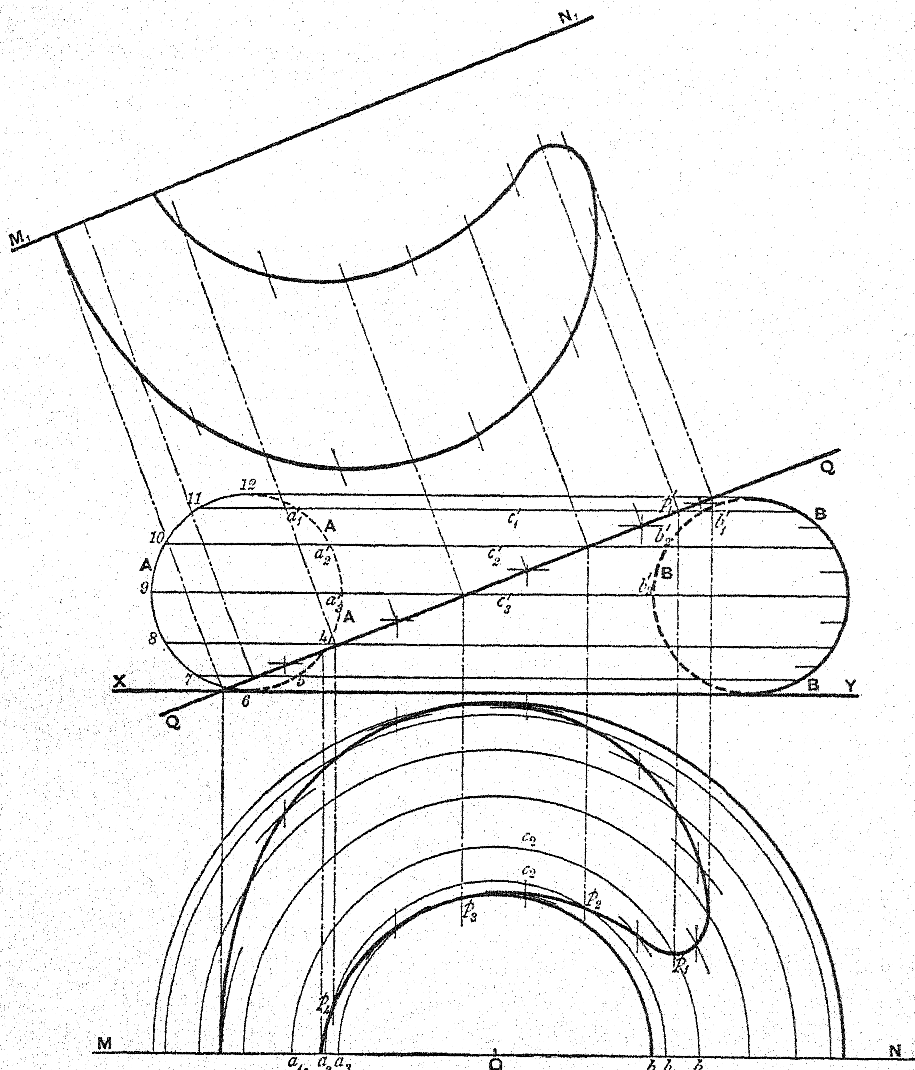


Fig. 56.

section is made up of two closed curves, one lying entirely within the other. If Q Q is parallel to X Y these two curves become two concentric circles. If Q Q does not cut either circle of the elevation, the curve of intersection is made up of two closed curves each lying outside of the other, the particular case of Q Q passing through the axis of the annulus giving two equal circles. If Q Q touch one of the circles, the curve of intersection will have a "double" point, and if it touch both circles there will be two "double" points on the curve.

CUTTING TOOLS.—V.

By R. H. Smith,

Professor of Mechanical Engineering, Mason's College, Birmingham.

[*Continued from p.* 217.]

SAWS AND MILLING MACHINES (*continued*).

Frame and Band Saws.—In hand and machine Frame saws the thin blade in tension is universally used, as also in Band saws. A very large proportion of the work of cutting logs into planks and boards,

which work is called the "reduction" or "conversion" of timber, is done by frame saws. In these a large rectangular frame is driven up and down in upright guides by crank and connecting-rod situated underneath the floor, and a number of saw-blades, sometimes as many as twelve or fifteen, are stretched vertically between the top and bottom cross-beams of this frame. The blades are spaced apart by blocks of hard wood or of iron of a thickness corresponding with that of the planks to be cut, the spacing being greater than that of the plank by the width of "kerf," or slit made by the saw-blade.

The blade of the band saw is very thin and flexible. It runs over two large pulleys, the frictional grip of the lower one of which on the blade supplies the driving force. The bearing of the upper pulley is pushed upwards by a spring or weighted lever to keep the saw-band tight. It has the advantage of running at a much higher speed than the frame saws; but, on the other hand, it is impracticable to arrange for several blades to run side by side, and thus only one cut at one time can be accomplished. The suitability of the band saw for large heavy work, such as big log-squaring, was long ago recognised in France, and, more recently, Messrs. A. Ransome & Co. have built a great number of very large size. Fig. 14 illustrates the machine. The pulleys here are 8 ft. in diameter, and are pushed apart with a force of from 4 to 5 tons, which is the stretching pressure put on the saw-band. The band itself is 8 to 9 in. wide, No. 16 B.W.G. thick, and about 60 ft. long. It runs with a cutting speed between 7,000 and 8,000 ft. per minute, and will cut through a depth of 75 in., while the rate at which the log can be fed through the machine may be as great as 60 ft. per minute. Otherwise expressed, the surface cut per minute may be 60 to 80 square feet in hard wood and 120 to 150 square feet in soft wood, the kerf being $\frac{1}{16}$ inch wide. The shafts of the band pulleys are 5 in. in diameter, of forged steel, and run in long self-lubricating swivel bearings. In smaller sizes the pulley overhangs the bearing; but for these heavy cuts an outside bearing is essential. Immediately above and below the cut the steel blade is guided and supported against the cutting pressure by a hardened steel roller at the back, and by hardened steel blocks at either side. The upper large pulley is capable of complete adjustment as to position, so as to guide the blade even during the heaviest cuts to such an extent as to leave the above steel roller very little work to do, and therefore to avoid risk of injurious heating of the blade due to intense concentrated pressure at this roller.

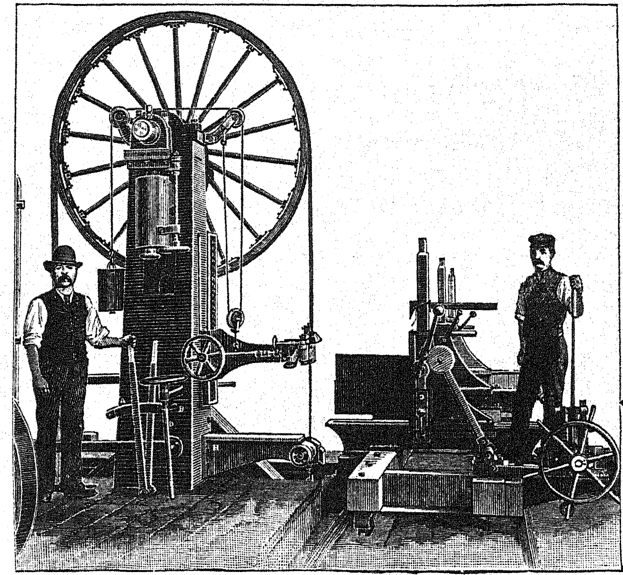


Fig. 14.

Circular Saws.—Rotating *circular* saws, on the other hand, are intermediate between the thrust and the pull saws. In them we may imagine successive radial segments of the circular blade to act as spokes of a wheel, and the cutting teeth to be driven through the wood by these spokes. The direction in which they are driven is perpendicular to the spokes, which are therefore, on the whole, thrown neither into tension nor compression, but are simply *bent*. The thin circular blade is usually 3 to 4 feet in diameter, but is sometimes 6 to 7 feet. The latter size may take about 12 horse-power to drive it. The blade is clamped between two large strong washers mounted on the horizontal steel driving spindle. Most of the upper half of the circular blade stands above the level of the cast-iron table over which the timber to be sawn is fed. This table supports an adjustable guide plate by help of which the timber is fed forwards along a straight line, and a uniform thickness is sawn.

Forms of Saw-teeth.—In all hand saws and in most machine saws the teeth are made solid with the blade. There is a great number of different shapes used for the teeth, some of which are found better for cutting across the grain, and others for

"ripping" in the direction of the fibre, some more especially suitable for hard, and some for soft wood. Fig. 15 shows seven different common forms of teeth. The first four shapes are for cross-cutting—*a* receiving the special name "peg" tooth, and *b* that of

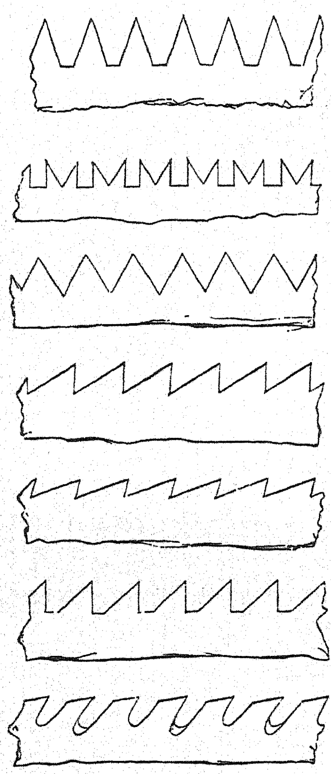


Fig. 15.

M tooth. The fifth (*e*) is suitable for ripping soft wood, and, when made of a smaller size, for sawing iron; *f* is one of the shapes commonly used in sash-sawing machines, in which logs are converted into planks; *g* is a form suitable for a circular saw.

In Fig. 16 are shown several forms drawn to an enlarged scale, and showing the "set" of the teeth.

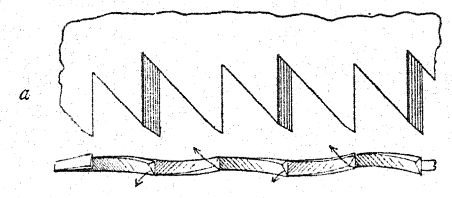
Setting Saw-teeth.—"Setting" is the bending of successive teeth alternately to one side and the other. The purpose of this is to make the width of the cut greater than the thickness of the blade, so that the blade may pass to and fro without much friction. Greater power being required for cross-cutting than for ripping, and the cut surfaces—composed, as they are, of bundles of fibres perpendicular to the surface—being less yielding than those parallel to the grain, a large amount of set is given to cross-cut saws, and very little to ripping saws. The setting is best performed by striking down alternate teeth upon a small anvil specially made for the purpose. When all the teeth that have to be set to one side are struck down, the saw-blade is turned over, and the others are struck down to the opposite side. The teeth are, however, more commonly set over by means of a specially constructed pair of pliers upon which there is a stop which, as the pliers pull the tooth over, comes in contact with the blade, and thus regulates the angle through which the tooth is bent to the side. In filing the teeth to sharpen them, care must be taken to bevel the edges of alternate teeth opposite ways, and in the subsequent setting equal care must be taken to bend each set of teeth towards the side of the blade for which it has been sharpened—that is, so that the sharp bevelled edge will lie outwards on the side to which the tooth is bent. The M tooth is intended to cut both on the forward and backward strokes. The opposite sides of the M are, therefore, bevelled in opposite directions. The result is shown in *c*, Fig. 16.

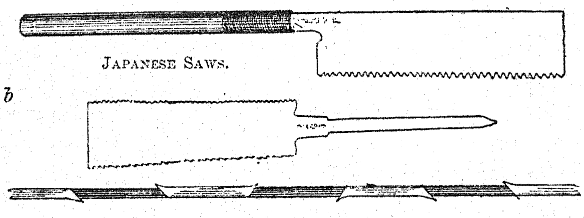
The above method of setting is the commonly adopted one, and is called "spring" setting. Another style is what is called "spread" set. In this the tooth is not bent, but has its extreme point hammered, or "swaged," so as to become broader than the thickness of the blade. This is more suitable for ripping than for cross-cutting.

Inserted Teeth.—In Fig. 17, *f* and *g* are two forms of "inserted" teeth that have been used for circular saws in America. The mode of fixing them in place is sufficiently evident from the diagram. The advantages of the inserted teeth are, that if a few teeth are broken they can be replaced easily, so as to make the saw as good as it was originally; that the diameter of the saw is not reduced by repeated filing in sharpening; that the teeth may be tempered much harder than the rest of the blade; and that the separate teeth being all individually forged and ground to gauge—*i.e.*, to one exact pattern—they are of necessity all exactly alike in size and shape.

The last point is a specially important one. If any tooth in a saw-blade does not stand so high as the level of the others, evidently it can do no work, and might as well be non-existent. If, on the other hand, its point is too high, it becomes buried too deep in the timber, and either will be rapidly worn and blunted, or will be broken off altogether. Until it is injured in one of these ways, it prevents the neighbouring teeth coming into proper action.

Sawdust Space.—The gap between successive teeth is cut out not solely with the object of forming a proper front face to the tooth, but also for the purpose of providing a space in which to store the sawdust produced by the tooth in front of which





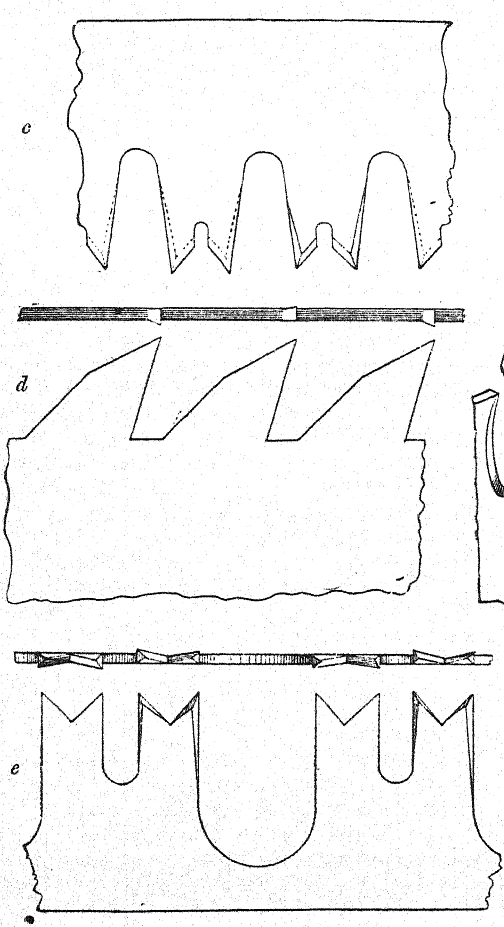


Fig. 16 (*a*, *b*, *c*, *d*, *e*).

the gap lies, during the time this tooth is passing through the wood; since, during this time, the sawdust has no opportunity of escaping out of the kerf. The gap must be large enough for this storage purpose, and therefore its size should depend on the greatest thickness through which the saw is designed to cut. It should also be larger the deeper the tooth is intended to cut, that is, the stronger the tooth is made.

Cutting Speed and Feed.—Circular saws are made to cut usually at the speed of about 9,000 feet per minute, but in America it has been found practicable to use one-and-a-half times that speed. Saws running at the higher speeds are ground so as to make the thickness of the blade at the periphery considerably thinner than at the centre. The object of this reduction at the edge is to obtain as little weight as possible at the points where the velocity is highest, in order to reduce the risk of breakage by centrifugal force, and at the same time to obtain as thin a kerf as

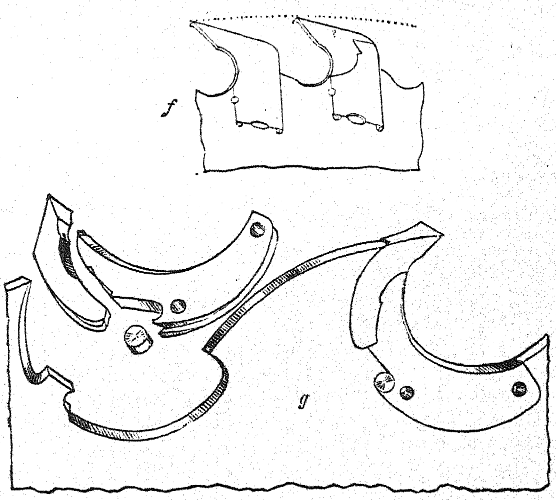


Fig. 17.

possible. At such high velocities the periphery vibrates rapidly from side to side through a small range, the consequence being that the kerf cut is much wider than the breadth of the faces of the teeth. The greater thickness at the centre is required for strength.

A saw cutting with the peripheral speed of 9,000 feet per minute can be fed forward at a rate varying from 30 to 100 feet per minute, according to the nature of the work done. If the feed is 60 feet per minute, then the advance will be $\frac{60}{9000} = \frac{1}{150}$ foot = ·08 inch for every foot of

peripheral movement. If the distance from point to point of the teeth is 2 inches, *i.e.*, six teeth to the foot, the depth of cut for each tooth is evidently $\cdot\frac{0.8}{6} = \cdot 013$, or $\frac{1}{77}$ inch only. At the rapid feed, 100 feet per minute, that is about $1\frac{1}{7}$ mile per hour, the depth of cut is no more than ·022 or $\frac{1}{45}$ inch.

The very rapid feed that can be employed with saws in good order upon the softer qualities of timber is therefore by no means surprising when considered in connection with the very high peripheral velocity. Of course, for cross-cutting the feed cannot be nearly so rapid.

Horse-Power.—The power required for sawing depends very greatly on the condition in which the teeth are kept. It is the worst possible economy to spare labour in keeping the teeth sharp, to their true shape, and all equally high. Saws are most commonly re-sharpened by hand-filing, but they can be more expeditiously and more uniformly dressed by one of the numerous special machines made for the purpose, in which the teeth are ground by a revolving emery disc. Circular saws have to be dismounted, and taken to the sharpening machine. In order to save time it is necessary to have different blades for the same machine, so that it need not stand idle while one blade is being re-dressed.

The horse-power required for sawing machines varies with the feed, and the horse-power actually supplied to them in common practice depends greatly on the character of the duty to be performed. If the saw is infrequently used, only sufficient power is supplied to enable the work to be done at a slow rate of feed, because in this case the loss of time involved in the slowness of feed is of little importance. But if the saw is used for a constant special duty—if, for instance, it is specially constructed and used for the production of railway sleepers from the rough logs, or for the conversion of heavy timber into planks, since such work goes on continuously—ample power is given to the saw to enable it to be used to its full capacity. The following examples are given on the authority of Grimshaw.

GANG SASH SAWS, OR SAW FRAMES.

Number of Saws.	Length of Blade in feet.	Width of Blade in inches.	Gauge of Blade, B.W.G.	Stroke in inches.	Number of Strokes per minute.	Feed per Stroke in inches.	Horse-power used.	Width of Double Belt.	Diameter of Pulley in inches.	Height of Teeth in inches.	Spacing of Teeth in inches.	Width of Kerf in inches.	Capacity in one day of 10 hours.
21	$3\frac{1}{2}$	7	13	20	300	$\frac{5}{8}$	70	24	48	1	$1\frac{1}{8}$	$\frac{3}{16}$	80 M
30	5	7	11, 12	22	200	$\frac{5}{8}$	35	16	42	$1\frac{1}{4}$	$1\frac{3}{4}$	$\frac{3}{16}$	35 M

BAND SAWS.

Width of Blade in inches.	Gauge of Blade, B.W.G.	Diameter of Saw Pulley in inches.	Revolutions per minute.	Feed per minute in feet.	Horse-power used.	Width of Single Belt in inches.	Diameter of Driving-Pulley in inches.	Height of Teeth in inches.	Spacing of Teeth in inches.	Width of Kerf in inches.	Capacity in one day of 10 hours.
4	18	60	400	25	12	8	30	$\frac{1}{2}$	$1\frac{1}{2}$	$\frac{1}{16}$	10
5	16	72	350	30	15	10	30	1	2		20

CIRCULAR SAWS.

Kind of Teeth.	Diameter of Saw in inches.	Gauge at Centre.	Gauge at Rim.	Number of Teeth.	Spacing of Teeth.	Revolutions per minute.	Feed per Revolution in inches.	Width of Kerf.	Horse-power used.	Width of Double Belt.	Diameter of Driving-Pulley in inches.	Capacity in one day of 10 hours.
Solid .	56	5	7	48	$3\frac{5}{8}$	600	$3\frac{1}{2}$	$\frac{1}{4}$	30	10	24	12
Inserted	72	6	8	72	$3\frac{1}{8}$	680	12	$\frac{1}{4}$	80	18	23	50
Solid .	60	4	8	64	$2\frac{15}{16}$	850	6	$\frac{1}{4}$	80	20	30	55
Inserted	60	6	7	34	$5\frac{1}{2}$	400	2	$\frac{1}{4}$	25			10

All the above saws—sash, band, and circular—were used on pine with the above speeds, feeds, and horse-powers.

Saws for Iron.—Small circular saws of 1 to 3 inches in diameter are much used for cutting the slits in heads of screw nails and metal screws, and also for making slits in various metal articles in the smallware trades. The cutting speed of the teeth is very much smaller than that of wood saws. It is greater for brass than for iron, and greater for iron than for steel. No lubricant is used with brass or cast-iron, but with steel and iron oil or soap-and-water are used in order to keep the tool and the work cool.

Circular saws are also used for cutting iron bars to the lengths desired. Except for small sizes, it is usual to heat the iron to a red heat. The heating softens the iron, and, of course, makes it much more easy to cut it, so that bars and plates 2 or 3 inches thick can be cut without destroying the saw teeth. Recently, circular saws have been used for cross-cutting billets of iron and steel 8 inches and 9 inches square. In saws intended for heavy work, the saw is arranged to run through a trough of cold water, in order to keep it cool, and prevent it from losing its temper. Powerful band saws have been lately used for sawing through great depths of iron and steel. The largest band used by Messrs. Hulse and Co. is $2\frac{1}{2}$ inches wide, and runs at 40 to 50 feet per minute, the tooth pitch varying from $\frac{1}{8}$ to $\frac{1}{4}$ inch.

DRAWING FOR CARPENTERS AND JOINERS.—V.

[*Continued from p.* 221.]

DOVETAILING.

DOVETAILING is of three kinds—common, lap, and mitre. *Common* dovetailing shows the form of the pins or projecting parts, as well as the excavations made to receive them. Fig. 64 shows the ends of the two boards *a* and *b* to be thus joined, and Fig. 65 shows the joint completed. Fig. 66 represents a variation of this form used in attaching the fronts of drawers to the sides, and for similar purposes. Here the dovetail is shown on the one side only, a ledge being left at the end of *a*, so that the ends of the dovetails of the side *b* do not penetrate quite to the front.

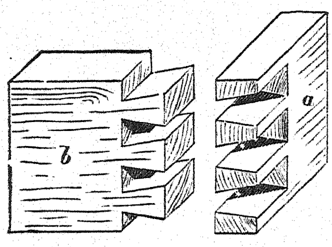


Fig. 64.

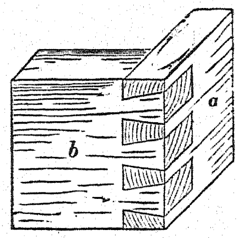


Fig. 65.

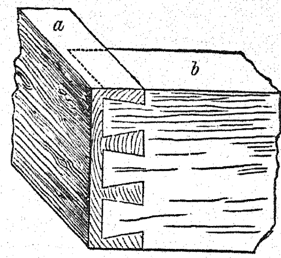
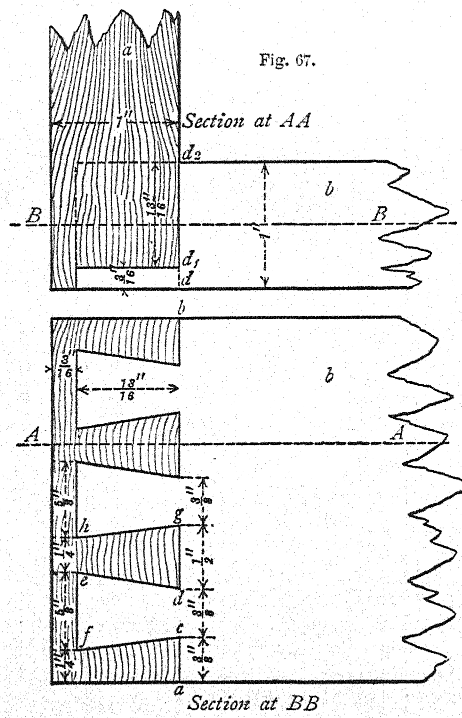


Fig. 66.

Lap dovetailing (Figs. 67 and 68) is similar to this, but in that system the ends of the dovetails of the side *a* are shortened, and the recesses which are to receive them in *b* are not cut through; when joined together, therefore, only the ledge is visible on the return side. Fig. 67 is sectional plan and elevation, and Fig. 68 is a quasi-perspective view. The two outside dovetails *p p* of the side *a* are not shortened like the others *q q*, as then there would be left at the corners of *b* weak parts which might be very easily broken off.



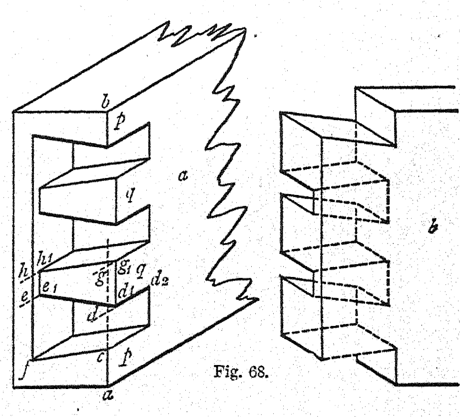


Fig. 68.

Mitre dovetailing—sometimes called also secret dovetailing—conceals the dovetails, and shows only the mitre at the edges. The manner in which this joint is effected will be understood from Fig. 69, in which the two parts A and B are given, each part being lettered to correspond with the position it is to occupy when the sides are joined. Concealed dovetailing is particularly useful where the faces of the boards are intended to form a salient angle, that is, one which is on the *outside* of any piece of work; but where the faces form a

re-entrant angle, that is, a joint to be seen from the *inside*, common dovetailing will answer best; for, first, it is stronger, because the dovetails pass

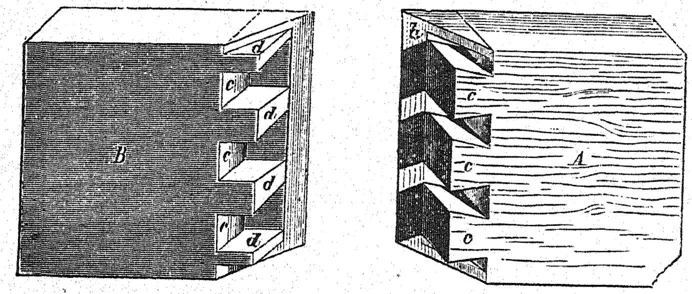


Fig. 69.

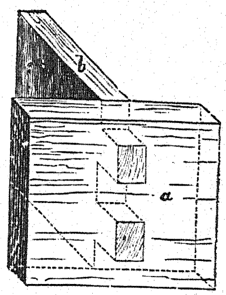


Fig. 70.

entirely instead of only partly through; secondly, it is cheaper, for the dovetails which go through the whole wood take up so much less time in working than where a mitre has to be left; and further, if well executed, the dovetails are, by the very nature of the work, concealed internally.

Fig. 70 exhibits a method of joining two boards at

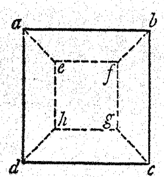


Fig. 71.

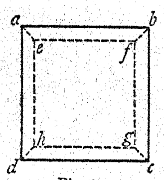


Fig. 72.

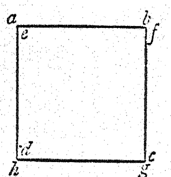


Fig. 73.

Fig. 74.

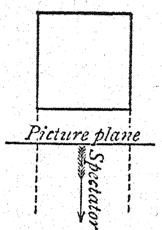


Fig. 75.

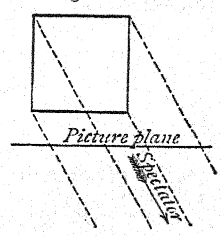


Fig. 76.

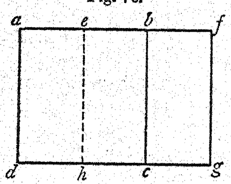


Fig. 77.

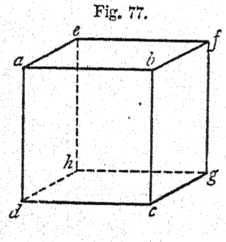


Fig. 78.

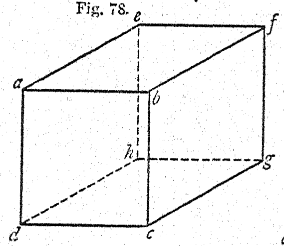
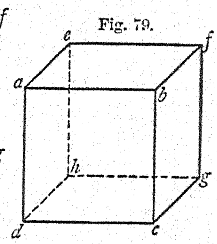


Fig. 79.



right angles to each other. This is the simple mortise and tenon, and will not require any explanation.

Examples 15—20.—Draw the examples shown in Figs. 32, 34, 36, 60, 63, 67 half full size.

INCLINED PARALLEL PROJECTION.

The drawings the student has done up to the present are all orthographic projections (*see* lessons on Projection). These drawings in many cases do not present the object as seen by the eye of a spectator; and we wish therefore to produce drawings which will combine the ease of construction of orthographic projections with the clearness and legibility of perspective drawings.

Let a cube be placed before the eye of a spectator with its front face at right angles to the line joining the spectator's eye to the centre of the cube. The appearance will be as shown in Fig. 71. Here the back face *e f g h* appears smaller than the front face *a b c d*. Thus the size of any part of the drawing depends not only on the size of the corresponding part of the object, but also on its position; the further away from the spectator's eye the object is, the smaller relatively will be the corresponding drawing. Suppose now the cube be placed further and further away from the spectator, the sides

a b c d and *e f g h* in the drawing will be more and more nearly equal (Fig. 72). Finally, if the distance between the cube and the spectator be so great that the lines joining the corners of the cube to the spectator's eye are sensibly parallel, the appearance will be as in Fig. 73. We have here a *parallel projection* of the cube, the projectors being at right angles to the picture plane or plane of projection. Fig. 74 is a plan showing the relative position of the cube and plane of projection, and the direction of the rays or projectors to the spectator's eye. In Fig. 73 therefore any part of the object which is parallel to the plane of projection has its corresponding projection of equal size. If now the cube be removed to the left of the spectator (Fig. 75), its front face being still parallel to the plane of projection, the projection obtained is shown in Fig. 76. This projection exhibits the faces *b c g f* and *a d h e* as well as the two faces (coincident) shown in Fig. 73. If the cube be below the spectator's eye as well as to the left, the projections (Figs. 77, 78, and 79) may be obtained. These projections exhibit all the faces of the cube —*i.e.*, if the back edges be dotted—and are a series of quasi-perspective drawings of the cube. By suitably placing the cube relative to the picture plane and spectator's eye, the projections *a e*, *b f*, *c g*, and *d h* of the edges at right angles to the front face may be made to assume any requisite position and length. In practice it will be most convenient to draw the edges—which in the object are at right angles to the front face—at some angle that can be easily drawn. For example, in Figs. 77 and 78 the edge *b f* is drawn at an angle of 30° with *a b* produced; in Fig. 79 the angle is 45°. The angles 30°, 45°, and 60° are the most convenient to use. In Figs. 77 and 79 the length *b f* measured on the drawing is half the corresponding length on the object in space. In Fig. 78 *b f* is equal to the corresponding true length. In working drawings, the edges at right angles to the plane of projection should be measured off full length, or foreshortened to some easy sub-multiple of the true length, say one-half, one-third, or one-fourth. In "Die Werkzeichnung für Bauausführung," by C. W. O. Schmidt, a drawing in which this edge is measured off full length is called "isometric," but as this term has already a totally different meaning in English (*see* lessons on Isometric Projection) we will call this drawing, and also drawings in which this edge is foreshortened, "inclined parallel projections" or "quasi-perspective" drawings.

Example 21.—Draw the inclined parallel projection shown in Fig. 33. The angle shown in Fig. 33 for the edges at right angles to the plane of projection is 30°, and the foreshortening is one-half. The points *a b c d e* are first drawn exactly the same as in Fig. 32, and lines inclined 30° drawn through them. The width $e\,e_1$ or $d\,d'_1$ is marked off, foreshortened as assumed. The rest of the drawing requires no explanation.

Examples 22–28.—Draw the inclined parallel projections shown in Figs. 35, 37, 39, 41, 58, 61, 68.

In Figs. 39 and 41 the dimensions of the timbers may be taken the same as in Fig. 36.

In Fig. 41 there is no foreshortening.

In Fig. 41, the part *h d l k b f n m* should be drawn first, exactly as in Fig. 40, and through these points lines drawn at 30° with *b f*, and the thickness *n n'* or *m m'* marked off. Draw also the triangle *d g l* as in Fig. 40. $h\,h_2$ and $g\,g_2$ are each equal to two-thirds of *m m'*, and $d\,d_3$, $g\,g_3$, $l\,l_3$ are each equal to one-half *m m'*. The thick lines indicate the proper form of the timber. The drawing of the upper part is done in a similar manner.

In Fig. 41_2 the preliminary construction lines shown thin render the drawing so clear that no further explanation is necessary.

In Fig. 68 draw the line *a b*, and mark off *a c*, *c d*, *d g* as in Fig. 67. From *c* and *d* draw lines at 30°, mark off $d\,d_1$, $d_1\,d_2$ along the line through *d*, half the corresponding lengths in Fig. 67. The rest of the drawing should be evident.

Example 29.—To draw a circle in quasi-perspective, its plane being at right angles to the plane of projection. In Fig. 80, a circle is drawn on the

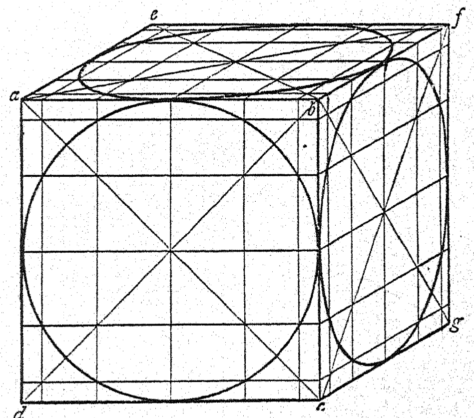


Fig. 80.

front face of a cube and touching the sides of the face. A number of points (in this case 12) is taken on the circumference of the circle, and projectors taken to the edges *a b*, *b c*, *c d*, *d a* of the cube. The edge *b f* is divided in the same ratio as *a b* is divided by the projectors from the points on the circumference of the circle. Projectors from the

points of division of $b\,c$ and $b\,f$, parallel to $b\,f$ and $b\,c$ respectively, determine by their intersection points on the circumference of the circle inscribed in the square $b\,f\,g\,c$. These points are joined by a fair curve, which will be the required projection of the circle.

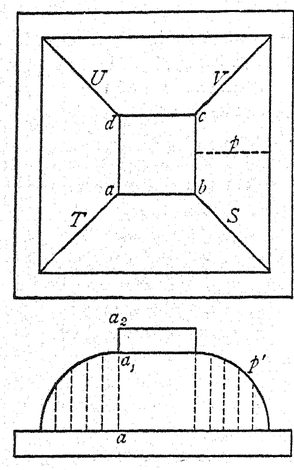


Fig. 81.

It will be noticed that the figure $b\,f\,g\,c$ with the included lines is just a distorted copy of the figure $a\,b\,c\,d$ and its included lines. Remembering this, it is easy to determine the proper points through which the curve must be drawn.

In arranging a drawing care should be taken to avoid having circles in planes at right angles to the projection plane, since the construction given in

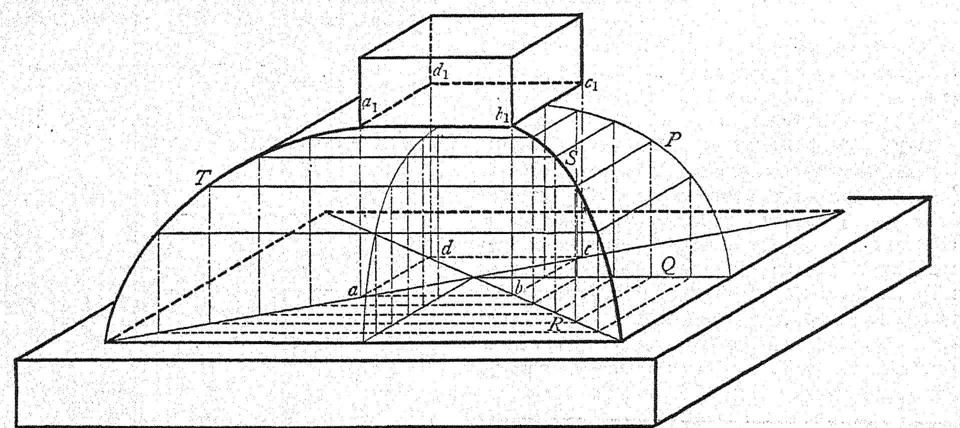


Fig. 82.

Example 29, if repeated very often, will make the execution of the drawing rather laborious. The position of the object to be drawn should be so arranged that, if possible, all circles and curved lines on it are parallel to the plane of projection. This of course is not always possible, and the student must therefore know the construction of Example 29.

Example 30.—To draw an inclined parallel projection of the object represented in Fig. 81 by plan and elevation.

We will arrange the object so that a pair of faces of the square prisms forming part of it are parallel to the picture plane. The square prism at the base should be drawn first; this presents no difficulty. Then on the top of this prism a projection $a\,b\,c\,d$ of the smaller top prism should be drawn. From a, b, c, d draw vertical projectors, marking off $a\,a_1$, $a_1\,a_2$, etc., equal to the corresponding dimensions in Fig. 81. The rest of the drawing of the small prism presents no difficulty.

To draw the dome-shaped part of the solid, imagine it to be cut by a plane P (Fig. 81) through its centre and parallel to the picture plane. The projection of this section p (Fig. 82) will evidently be the same as the elevation p' (Fig. 81). Take a number of points on this curve P, and draw projectors from them to the top of the bottom prism. The feet of these projectors all lie on the line Q. From the points on Q draw projectors parallel to $c\,b$ to meet the diagonal line R. From the points on R draw vertical projectors, and from the points on P draw projectors parallel to $c_1\,b_1$; the intersection of corresponding pairs of these projectors will determine points on the projection S of the corner of the dome. Through these points a fair curve is drawn freehand. A similar construction determines T, the projection of another corner of the dome. The construction lines for S and T are all shown, and a careful inspection of the figure should make the method plain to the student. In order not to crowd the figure, the projections of the two back corners, U and V, of the dome are not shown. A common tangent must be drawn to the

projections T and U; this tangent should be of course parallel to $a_1 d_1$.

Example 31.—Draw the joint shown in Fig. 60 in parallel projection. This example is a further application of the principles involved in Examples 29 and 30. Great care must be observed in executing the drawing. Draw to a scale twice full size.

PHOTOGRAPHY.—V.

BY T. C. HEPWORTH, F.C.S.

[*Continued from p.* 224.]

EXPOSURE SHUTTERS.

THE exposure shutter—commonly but erroneously called an instantaneous shutter—is a necessary outcome of the rapid pictures obtainable with modern gelatine dry plates. With some subjects it is a necessity, but its use in season and out of season is much to be deprecated. The hand

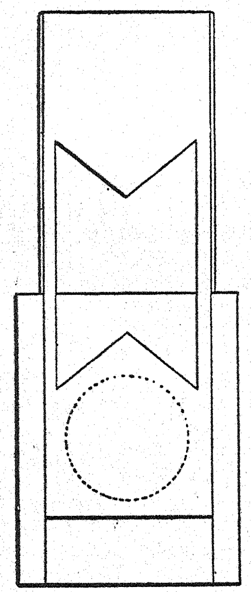


Fig. 32.

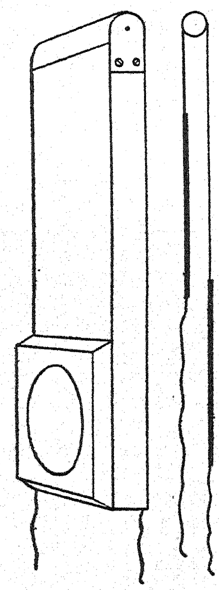


Fig. 33.

camera must be fitted with some kind of *quickly* acting shutter, but with the ordinary instrument no shutter is required for the great majority of pictures taken. A shutter is a valuable adjunct to the studio camera, and generally takes the form of a velvet-covered flap working inside the instrument so that it cannot be seen by the sitter. It is especially valuable in taking the portraits of children.

For out-door work the shutter used may take a position either in front of the lens, it may work in the diaphragm-slot between the combinations of a doublet, or it may work in the camera itself—sometimes taking the form of a blind with a slit across it—working just in front of the sensitive plate.

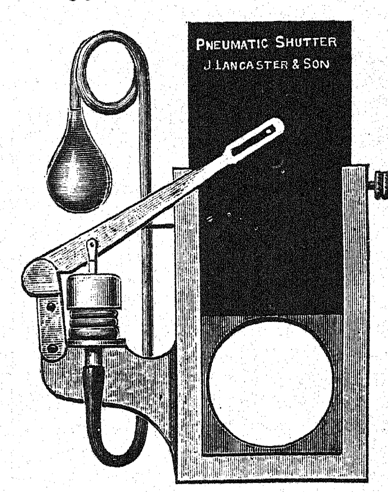


Fig. 34.

Whatever type of shutter be chosen, it should work without the least jar to the camera, or at any rate no vibration should be communicated to the apparatus until the exposure is over.

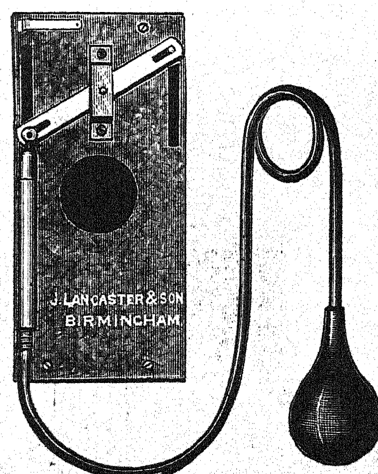


Fig. 35.

The simplest form of shutter is that known as the drop-shutter, shown at Fig. 32. In this case a frame fits over the lens, containing at each side a groove, in which falls by gravity a slip of wood or ebonite, having an orifice in it of larger size than

the lens aperture. This orifice it will be seen in the example given is not rectangular—a portion both at the top and bottom encroaching on the central space. The reason of this is to counteract the less brilliantly illuminated edges of the plate by robbing the central portion of some of its light.

Places' shutter, shown at Fig. 33, is a useful form. In this we also have a frame fitting on the hood of the lens, but in this case it is closed in, and contains two grooves, in each of which moves a plate of ebonite, the two plates being hung by cords over a roller at the top of the instrument, as shown at the side of the diagram. A string from each plate hangs below, and the effect of pulling either is to raise one plate, and to pull down the other. The writer has found this shutter useful for taking animals and children in the open air, for the exposure with it can be regulated from about the tenth part of a second to as long a period as may be convenient.

A shutter on the go-and-return principle is shown at Fig. 34, and this introduces us to an important feature of most shutters, namely, the pneumatic release. By squeezing the air from an india-rubber ball at the end of a tube of similar material the mechanism is set in motion without communicating vibration to the camera, as would be the case if actual touch of the hand were necessary. This shutter, like many others, is so arranged that it will remain open as long as pressure is kept upon the ball.

Fig. 35 exhibits the see-saw shutter, in which a

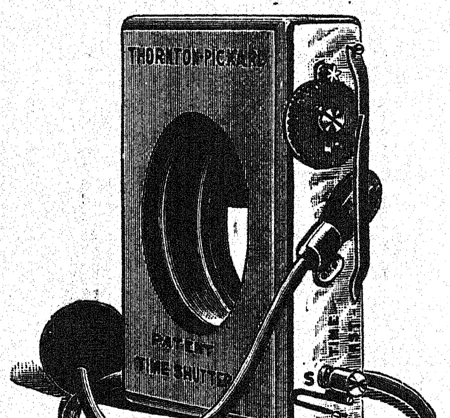


Fig. 36.

plate bored with a hole, as in the case of the drop shutter, moves across the lens aperture on pressure of a pneumatic ball.

In the Thornton-Pickard shutter (Fig. 36) we have an example of the rolling-blind principle. This shutter can be set so as to give what is known

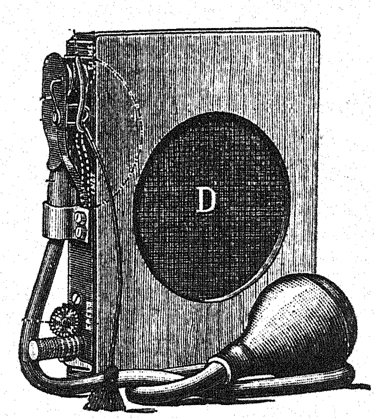


Fig. 37

as a *time* exposure, or it will work instantaneously. The shutter is a favourite one, and is largely used.

Another shutter working on the *blind* principle is Kershaw's (Fig. 37). This can also be used for *time* exposures, as well as for so-called *instantaneous* work. This shutter is so noiseless in operation that it is much used for photographing children and animals.

Many shutters now sold are far too complicated and delicate in their construction. A shutter should on the contrary be of such simple design that it cannot readily get out of order, and can be easily repaired by the user if anything goes wrong with it. It should be capable of being graduated as to speed of working, for certain moving objects—ships at sea, for instance—require far quicker exposure than would a city street full of people.

To ascertain the speed at which a shutter works, a good plan is to cause a white index pointer to move at a uniform speed—say one revolution per second—round a black dial with white division lines. As the pointer moves, it is photographed by aid of the shutter which it is required to test. The movement of the pointer will be indicated in the negative by a blurred mark, and the proportion which the length of this blurr bears to the circumference of the dial will indicate the fraction of a second at which the shutter works.

COPYING DOCUMENTS, DIAGRAMS, ETC.

The photographer is frequently called upon to make copies of pictures, diagrams, documents, etc., and a few brief directions as to the best manner of carrying out this work will be here briefly given.

It is frequently found in this work that the ordinary camera will not extend far enough to enable the operator to approach the object as closely as he requires to do to obtain an image of sufficient size. As a case in point, let us suppose that he requires to copy a cabinet picture the same size as the original, and that he is using a lens of 8-inch focus. In this case the object must be 16 inches in front of the lens, and the sensitive plate must be the same distance behind it; if therefore his camera does not extend to as much as that, the work cannot be done without further aid. It is obvious that the difficulty is increased should the copy be required to be slightly larger than the original.

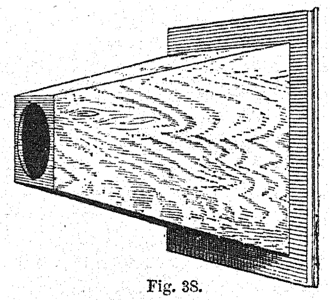


Fig. 38.

By fixing upon the camera front a cone of wood like that shown at Fig. 38, a remedy is at once found. The apex of the cone is pierced for the lens flange, while its other end is made to fit the groove into which slides the ordinary camera front. The advantage of having an extra flange or two for each lens employed is here indicated.

In copying pictures of any kind the first requisite is, to ensure that the copy is placed absolutely squarely in front of the camera, and this, although it appears to be the simplest thing possible, is by no means easy of attainment unless special apparatus is employed. The writer has constructed

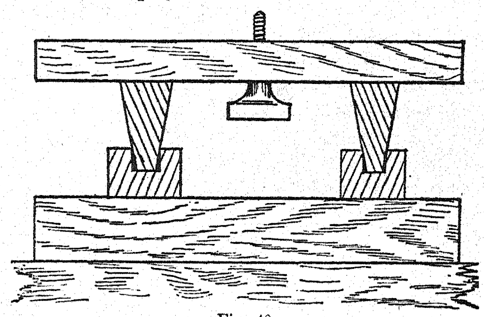


Fig. 40.

a copying-stand which has proved most useful in many different ways. It is a simple light platform which can readily be carried from room to room, or into the open air, about 4 feet 6 inches in height and 4 or 5 feet long. A common table might easily be adapted to the purpose. Its chief part is an upright board upon which the picture is fastened, in front of which is a kind of railroad—a couple of grooved wooden laths—on which slides a carriage having on its upper surface transverse rails. On these latter slides a super-carriage to which the camera is screwed. This apparatus therefore ensures that the object to be copied is squarely in front of the camera, and the latter can be made to

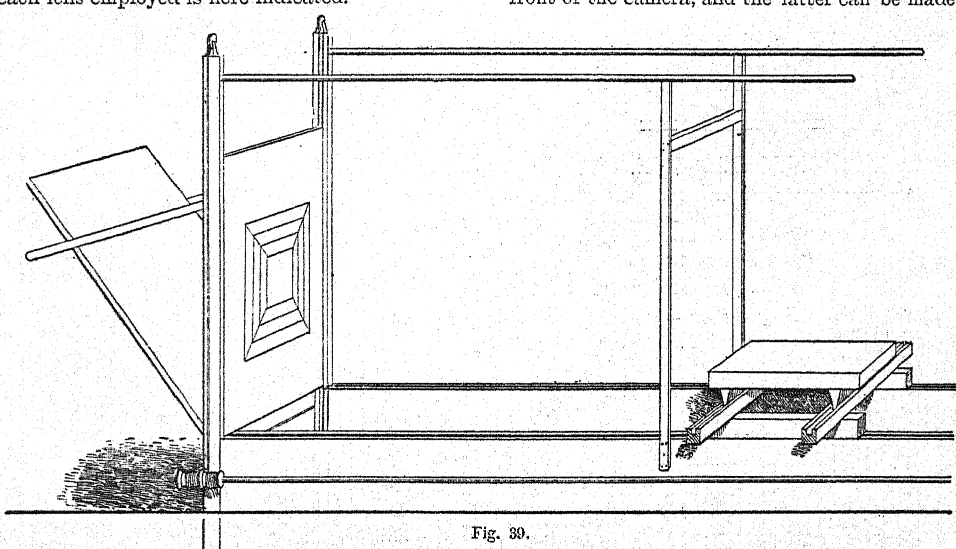


Fig. 39.

approach it or recede from it for focussing purposes, while at the same time the camera has a lateral movement by means of the super-carriage

to which it is fixed. The board to which the object is attached moves in vertical grooves, so that this completes an apparatus which has every required motion.

Fig. 39 shows the stand prepared for copying a negative, which is inserted in a carrier, and fitted into a frame which, for the time being, takes the place of the ordinary upright board or easel. At the back of this frame is a sloping board covered with white card to reflect the sky-light through the negative. The framework of laths above affords the means of throwing a dark cloth over the entire apparatus while the work is going forward.

Figs. 40 and 41 give details of the carriage, super-carriage, and rails which explain themselves.

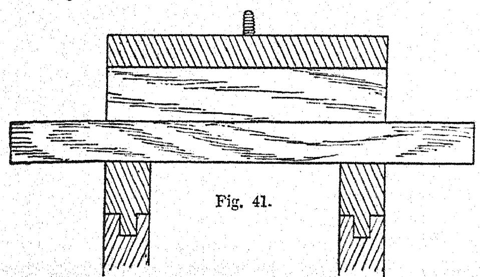


Fig. 41.

The same apparatus can be arranged for the reduction of lantern slides from negatives of larger size. In this case the easel-board must be removed, and upon the rails stands a lime-light jet behind a 6-inch condenser. In front of this condenser is an opening in which the negative to be copied is placed. A camera with a rectilinear lens completes the arrangement.

THE STEAM ENGINE.—V.

By Archibald Sharp, B.Sc., Wh.Sc., A.M.I.C.E.,
Instructor in Engineering Design at the Central Institution of the City and Guilds of London Institute.

[*Continued from p.* 256.]

HEAT OF FORMATION OF STEAM.

External Work of Evaporation.—We have already seen that 966 British Thermal Units are required to convert 1 lb. of water, under atmospheric pressure and at a temperature of 212°, into steam at the same pressure and temperature. Also the volume of 1 lb. of water at 212° and at atmospheric pressure is ·02 cubic feet, and the volume of 1 lb. of steam at the same pressure and temperature is 26·36 cubic feet. Consequently, the difference of volume is 26·34 cubic feet, and the work done against the pressure of the atmosphere is equal to the product of this difference of volume, and the pressure of the atmosphere 14·7 lb. per sq. in., or $14{\cdot}7 \times 144 = 2116{\cdot}8$ lb. per sq. ft. This product is $2116{\cdot}8 \times 26{\cdot}34 = 55756$ foot-lb., the thermal equivalent being 71·6 thermal units. This is called the "external work of evaporation"; its amount depends on the relation existing between pressure and volume during the formation of the steam. The case considered above—viz., constant pressure during formation—is the ordinary case of continuous generation of steam in a boiler, the steam being continuously taken away from the boiler to the steam-engine.

Internal Work of Evaporation.—The difference of the latent heat of evaporation (966 thermal units) and the external work of evaporation (71·6 thermal units) is 894·4 thermal units, and has been expended entirely in changing the molecular condition of the water. It is therefore called the internal work of evaporation, at a temperature of 212°, and is independent of the method of forming the steam.

If now dry saturated steam be formed at any other pressure, the latent heat of evaporation will be different. The internal work of evaporation and the external work, as well as the latent heat, will vary with the pressure of the steam. In Table II., the latent heat of evaporation and its two components—internal work and external work—are given.

Suppose 1 lb. of water to be placed in a closed vessel of a certain definite capacity, and suppose also that the air has been completely exhausted from the vessel. Then, whatever be the temperature of the water, the part of the vessel not occupied by the water in its liquid form will be filled by water-vapour, the pressure in the inside of the vessel depending on the temperature of the water. Thus, if the temperature of the water be 100°, we find from Table I. that the corresponding pressure in the closed vessel is ·942 lb. per sq. in. Now, let heat be applied to the water; its temperature will rise, some of it will be evaporated at once, and the pressure inside the vessel will also rise. The relation between pressure and temperature during the process is the same as given in Table I. The process goes on until all the water has been evaporated; the pressure and temperature, when evaporation is completed, depending on the volume of the closed vessel. During this process of evaporation it is evident that no external work has been done, and, consequently, the latent heat of evaporation in this case is less than when the steam is formed under a movable piston at constant pressure and, therefore, constant temperature. The latent heat of evaporation in this case is just equal to what we have already called the "internal work of evaporation," at the temperature corresponding to completion of evaporation.

Internal Work of Rise of Temperature.—The mechanical equivalent of the heat expended in

TABLE II.

Thermal Properties of Saturated Steam.

Absolute Pressure. p	Latent Heat of Evaporation under Const. Pressure. L		Internal Work of Rise of Temperature. h		Total Heat of Evaporation under Const. Pressure. H		External Work of Evaporation under Const. Pressure. E.		Internal Work of Evaporation. ρ		Total Internal Work of Evaporation from 32°. I	
Lb. per sq. in.	Th. U.	Ft. lb.	Th. U.	Ft. lb.	Th. U.	Ft. lb.	Th. U.	Ft. lb.	Th. U.	Ft. lb.	Th. U.	Ft. lb.
.085	1,092	851,000	0	0	1,092	851,000						
1·0	1,043	814,000	70	55,000	1,113	868,000	60·4	47,100	982	767,900	1,053	821,000
2·0	1,026	800,000	94	74,000	1,120	874,000	63·0	49,100	963	751,000	1,057	825,000
3·0	1,015	792,000	110	86,000	1,125	877,000	64·5	50,300	950	742,000	1,060	827,000
4·0	1,007	786,000	121	95,000	1,128	880,000	65·7	51,200	942	735,000	1,063	829,000
5·0	1,001	781,000	130	102,000	1,131	882,000	66·5	51,900	934	729,000	1,065	831,000
6	995	777,000	138	108,000	1,134	884,000	67·4	52,600	928	724,000	1,067	832,000
7	991	773,000	145	113,000	1,136	886,000	67·9	53,000	923	720,000	1,068	833,000
8	986	770,000	151	118,000	1,138	888,000	68·5	53,400	918	716,000	1,069	834,000
9	982	766,000	157	122,000	1,139	889,000	69·0	53,800	913	712,000	1,070	835,000
10	979	764,000	162	126,000	1,141	890,000	69·4	54,100	909	709,000	1,071	836,000
11	976	761,000	166	130,000	1,142	891,000	69·8	54,400	906	707,000	1,072	836,000
12	973	759,000	170	133,000	1,143	892,000	70·1	54,700	903	704,000	1,073	837,000
13	970	757,000	174	136,000	1,145	893,000	70·5	55,000	900	702,000	1,074	838,000
14	968	755,000	178	139,000	1,146	894,000	70·8	55,200	897	700,000	1.075	839,000
14·7	966	754,000	181	141,000	1,147	894,000	71·0	55,400	895	699,000	1,076	839,000
15	965	753,000	182	142,000	1,147	895,000	71·0	55,400	894	698,000	1,076	839,000
16	963	751,000	185	144,000	1,148	895,000	71·3	55,600	892	696,000	1,077	840,000
17	961	749,000	188	147,000	1,149	896,000	71·6	55,900	889	694,000	1,078	841,000
18	959	748,000	191	149,000	1,150	897,000	71·9	56,100	887	692,000	1,078	841,000
19	957	746,000	194	151,000	1,151	897,000	72·1	56,200	885	690,000	1,079	841,000
20	955	745,000	197	153,000	1,152	898,000	72·3	56,400	883	689,000	1,080	842,000
25	946	738,000	209	163,000	1,155	901,000	73·3	57,200	873	681,000	1,082	844,000
30	939	732,000	219	171,000	1,158	903,000	74·1	57,800	864	674,000	1,084	845,000
35	933	727,000	228	178,000	1,161	905,000	74·8	58,300	858	669,000	1,086	847,000
40	927	723,000	236	184,000	1,163	907,000	75·4	58,800	852	664,000	1,088	849,000
45	922	719,000	243	190,000	1,165	909,000	75·9	59,200	846	660,000	1,090	850,000
50	917	715,000	250	195,000	1,167	911,000	76·4	59,600	841	656,000	1,091	851,000
55	913	712,000	256	200,000	1,169	912,000	76·8	59,900	836	652,000	1,092	852,000
60	909	709,000	262	205,000	1,171	914,000	77·2	60,200	832	649,000	1,094	853,000
65	905	706,000	268	209,000	1,173	915,000	77·6	60,500	828	646,000	1,096	855,000
70	901	703,000	273	213,000	1,174	916,000	77·9	60,800	824	643,000	1,097	856,000
75	898	700,000	278	217,000	1,176	917,300	78·2	61,000	820	639,000	1,098	856,000
80	895	698,000	282	220,000	1,177	918,000	78·5	61,200	816	636,000	1,099	857,000
85	892	696,000	286	223,000	1,178	919,000	78·8	61,500	813	634,000	1,100	858,000
90	889	693,000	291	226,000	1,180	920,000	79·1	61,700	810	632,000	1,101	859,000
95	886	691,000	295	230,000	1,181	921,000	79·3	61,800	807	629,000	1,101	859,000
100	884	689,000	298	233,000	1,182	922,000	79·5	62,000	804	627,000	1,102	860,000
110	879	685,000	305	238,000	1,184	923,000	80·0	62,400	799	623,000	1,104	861,000
120	874	682,000	312	243,000	1,186	924,000	80·4	62,700	794	619,000	1,106	862,000
130	869	678,000	318	248,000	1,188	926,000	80·8	63,000	789	615,000	1,107	863,000
140	865	675,000	324	253,000	1,190	928,000	81·1	63,200	784	612,000	1,109	865,000
150	861	672,000	330	257,000	1,191	929,000	81·4	63,500	780	609,000	1,110	866,000
160	858	669,000	335	261,000	1,193	930,000	81·6	63,700	776	605,000	1,111	866,000
170	854	666,000	340	265,000	1,194	931,000	81·9	63,900	772	602,000	1,112	867,000
130	850	663,000	345	269,000	1,196	933,000	82·2	64,100	768	599.000	1,113	868,000
190	847	661,000	350	273,000	1,197	934,000	82·4	64,300	765	597,000	1,115	870,000
200	844	659,000	354	276,000	1,198	936,000	82·7	64,500	762	594,000	1,116	871,000
250	830	648,000	374	292,000	1,204	939,000	83·6	65,200	747	583,000	1,121	874,000
300	818	638,000	391	305,000	1,209	943,000	84·5	65,900	733	572,000	1,125	877,000

raising the water from some arbitrarily chosen standard temperature (usually 32° F.) to the temperature at which evaporation takes place, is called the internal work of rise of temperature. Table II., column 3, gives its value for the corresponding pressures in column 1.

Total Heat of Evaporation is the amount of heat required to raise a pound of water from 32° to a certain temperature, and evaporate it into steam at that temperature.

Let s be the volume in cubic feet of 1 lb. of water, and let v be the volume in cubic feet of 1 lb. of dry

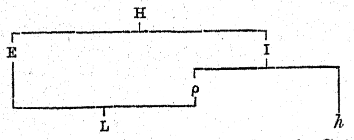
saturated steam at a pressure of p lb. per square inch or P lb. per square foot.

Let t be the corresponding temperature in degrees F.
" H " total heat of evaporation.
" L " latent heat of evaporation.
" ρ " internal work done during evaporation.
" E " external work of evaporation.
" I " total internal work of evaporation.
" h " internal work of rise of temperature.

We have then the following relations:—

$$L = \rho + E.$$
$$I = \rho + h.$$
$$H = L + h = \rho + E + h = E + I.$$
$$E = P\,(v - s).$$

The above equations are conveniently represented by Professor Unwin in diagrammatic form, thus—



The above notation is the same as in Cotterill's "The Steam Engine."

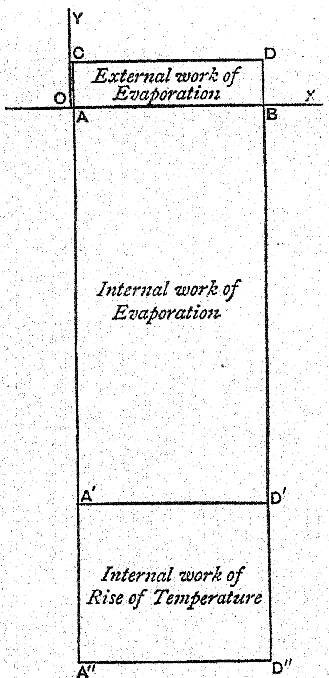


Fig. 37.

Internal Work Pressure. Heat Pressure.—The external work of evaporation is the product of a pressure, P, and a volume, $v-s$. Conceive the internal work done during evaporation to be the product of the same volume $(v-s)$, and a pressure, $\overline{P}$. Similarly conceive the internal work of rise of temperature to be the product of the same volume $(v-s)$, and a pressure, P′. Draw a diagram (Fig. 37), taking O X as the axis of volume and O Y as the axis of pressure. Set off along O Y, O B $= v$ and O A $= s$. Draw A C parallel to O Y and equal to P. Complete the rectangle A B D C; its area represents the external work of evaporation. On the same base, A B, draw a rectangle, A B D′ A′, of area equal to internal work done during evaporation; A A′ is, by definition, $= \overline{P}$. On the base A′ D′ draw a rectangle, A′ D′ D″ A″, of area equal to the internal work of rise of temperature; A′ A″ is, by definition, $=$ P′. A A′ is called the "total internal work pressure." P $+ \overline{P} +$ P′ is the pressure equivalent to the expenditure of heat or, more briefly, the "heat-pressure."

The above diagram conveys to the mind of a beginner a much clearer idea of the relative magnitude of the quantities involved than is possible by merely mentioning their numerical values. The conception is due to Cotterill.

Fig. 37 is drawn for a pressure of 100 lb. per square inch absolute. The line A C lies much closer to O Y than is shown in the figure.

PERFECT HEAT ENGINES.

A heat engine is an apparatus for converting heat into work. This definition evidently includes steam engines, hot-air engines, gas engines, and oil engines. In these engines the combustion of the fuel gives a supply of heat which is converted by the engine into work. In this sense the "engine" includes the whole of the apparatus used, for example in the ordinary case of a steam engine the "heat" engine includes both boiler and engine. These engines have all something in common, and

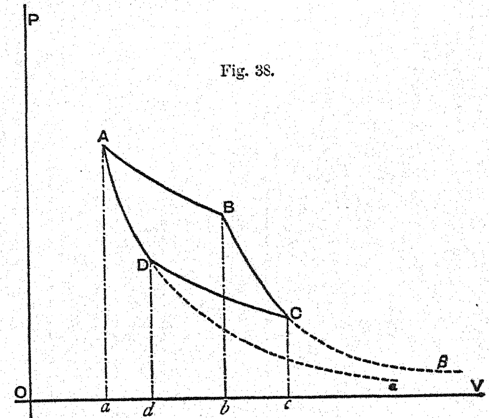


Fig. 38.

it is convenient to study the action of an ideal heat engine before going into details of any particular one.

Cycle.—If a fluid undergoes a series of changes of pressure and volume, and finally returns to its initial pressure and volume, it is said to work in a cycle. In Fig. 38 the initial state is represented by A, and the fluid, after undergoing the changes represented by B, C, D, returns to its initial state A.

Carnot's Cycle or *Carnot's Engine.*—Suppose a portion of a fluid to be enclosed in a cylinder fitted

with a perfectly fitting piston which is also perfectly frictionless. Let the initial pressure and volume of the fluid be represented by A (Fig. 38); let the cylinder be placed on a very large hot body of temperature t, and suppose the cylinder walls to be *perfect conductors* of heat. If the piston be allowed to move outwards, the fluid will expand isothermally, its temperature being always t. Let the isothermal expansion go on until the state of the fluid is represented by B. At this stage let the cylinder be removed from the hot body and further imagine the cylinder and piston *now to be perfect non-conductors of heat.* If the piston move out still further, the expansion of the fluid takes place without any communication of heat, and is represented by the adiabatic B C. During this adiabatic expansion the temperature of the fluid has fallen from t_1 to t_2, t_2 being the temperature corresponding to state C. Now let the cylinder be placed in communication with a very large cold body of temperature t_2, and suppose heat to flow freely from this body through the cylinder walls to the fluid. If now the piston be *driven in*, the fluid will be compressed and the thermal communication being perfect, its temperature remains t_2. This compression is represented graphically by the isothermal C D. At this stage let the cylinder be removed from the cold body, and imagine it once more to become a perfect non-conductor of heat; if the piston be moved in further, the compression is represented by the adiabatic D A, the point D being chosen so that the adiabatic through D passes also through A. The fluid has now worked through a complete cycle, and the above series of operations may be repeated indefinitely. This cycle is called Carnot's cycle, and was conceived by him in 1824. It forms one of the few important fundamental conceptions of the science of thermo-dynamics.

From the points A B C D (Fig. 38), draw perpendiculars A a, B b, &c., to the line of zero pressure, and let the adiabatics B C and A D be produced indefinitely. Then during the first stage of the cycle the external work done by the fluid is equal to the area a A B b, and the heat absorbed is equal to the area α A B β. During the second stage of the cycle there is no transmission of heat to or from the fluid, but the external work done by the fluid is equal to the area b B C c. During the third stage, the work done in compressing the fluid is the area c C D d, while the heat given up by the fluid to the cold body is the area β C D α. During the fourth stage there is no transmission of heat, while the external work done in compressing the fluid is d D A a. The difference of the work done *by* the fluid while expanding and that done *on* it during compression is therefore equal to the A B C D. Thus the net work done during the cycle is the mechanical equivalent of the difference of the heat taken by the fluid from the hot body, and that given by it to the cold body.

The hot body and the cold body in the above cycle correspond to the furnace and condenser respectively in an actual engine.

Reversible Cycle.—Carnot's cycle is reversible, *i.e.*, all the operations can be performed in the opposite direction. In this case the path of the fluid would be A D C B, the work done *on* the fluid is the area A D C B, and there is a transfer of heat from the cold body to the hot body. Such a cycle is the cycle of a perfect refrigerating machine, and forms the basis of the action of all machines for the mechanical production of cold.

As an example of a non-reversible cycle, let the fluid be kept at constant volume, and when its temperature is t_1, let it be placed in thermal communication with the cold body; its temperature will fall to t_2, and the corresponding part of the diagram is B C (Fig. 39). It is plainly evident that this part of the cycle is not reversible—*i.e.*, by simply keeping the fluid at constant volume and in contact with a cold body of temperature t_2, its temperature cannot by any means rise to t_1.

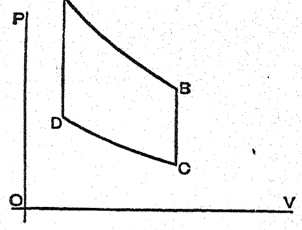


Fig. 39.

The Conditions for a Reversible Cycle are then that the fluid when receiving heat or giving up heat should be of exactly the same temperature as the hot body or the cold body with which it is in thermal communication. An engine in which the cycle is reversible will be a "perfect heat engine."

Efficiency.—If H is the amount of heat supplied to the fluid from the hot body, and W the work done, both measured in foot-pounds, the fraction $\frac{W}{H}$ is called the efficiency of the engine.

Carnot's Principle.—No engine or collection of apparatus of whatever construction can have an efficiency greater than an ideal Carnot engine working between the same temperature.

Second Law of Thermodynamics.—In the example given above of a non-reversible cycle, we mentioned that heat would not flow from the cold body into the fluid at a higher temperature. This is a matter of every-day experience, and is of such fundamental importance in thermodynamics as to be regarded as a "law." Clausin's statement of

this second law is, "Heat cannot pass from a cold body to a hot one by a purely self-acting process." Thomson (now Lord Kelvin) states the law thus: "It is impossible by means of inanimate material agency to derive mechanical effect from any portion of matter by cooling it below the temperature of the coldest of surrounding bodies."

Thomson's Absolute Scale of Temperature.—We have already given a definition of temperature depending on the rate of expansion of some substance chosen, and which therefore depends on the physical properties of the substance. We are now in a position to understand the conception of an absolute scale of temperature quite independent of the properties of any particular substance. Let $a\,b\,c$ (Fig. 40) be an isothermal of the fluid used in

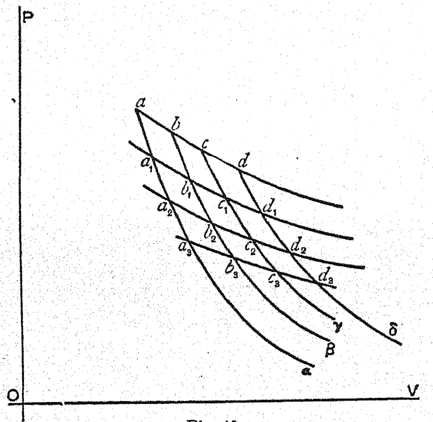


Fig. 40.

Carnot's engine, and let the quantities of heat absorbed during the expansions $a\,b$ and $b\,c$ be equal. Through a, b, c draw adiabatics $a\,\alpha$, $b\,\beta$, $c\,\gamma$. Let $a_1\,b_1\,c_1$, $a_2\,b_2\,c_2$ be other isothermals intersecting the adiabatics. Then the areas $\alpha\,a\,b\,\beta$ and $\beta\,b\,c\,\gamma$ are equal, and also the areas $\alpha\,a_1\,b_1\,\beta$ and $\beta\,b_1\,c_1\,\gamma$. Therefore the areas $a\,b\,b_1\,a_1$ and $b\,c\,c_1\,b_1$ are equal. That is, the areas between the adiabatics corresponding to equal additions of heat cut off by any pair of isothermals are equal. Now if the isothermals $a\,b\,c$, $a_1\,b_1\,c_1$, $a_2\,b_2\,c_2$ are taken so that the areas $a\,b\,b_1\,a_1$ and $a_1\,b_1\,b_2\,a_2$ are equal, the absolute scale of temperature is so graduated that the differences of temperatures $t-t_1$ and t_1-t_2 are equal. Let x be the number of foot-pounds in the area $a\,b\,b_1\,a_1$, then the quantity of heat absorbed during expansion $a\,b$, that is, the area $\alpha\,a\,b\,\beta$ will be equal to $x, \dfrac{t}{t-t_1}$ foot-pounds. Similarly if the fluid expand from a_1 to b_1 the heat absorbed is equal to $\dfrac{x\,t_1}{t_1-t_2}$ foot-pounds. The scale of absolute temperature, as defined above, does not differ very much from that of the air thermometer.

Efficiency of Perfect Heat Engine.—In the above diagram let $a_1\,b_1\,b_2\,a_2$ be the graphic representation of a Carnot cycle. The work done $= x$ foot-pounds, and the heat absorbed $= \dfrac{x\,t_1}{t_1-t_2}$, consequently the efficiency

$$= \frac{\mathrm{W}}{\mathrm{H}} = \frac{x}{\dfrac{x\,t_1}{t_1-t_2}} = \frac{t_1-t_2}{t_1}$$

This efficiency depends only on the temperatures between which the fluid works, and is quite independent of the nature of the fluid used.

Entropy.—In Fig. 40 let a series of isothermals differing by unit temperature be drawn, and let the states a, b, c, d correspond to equal increments of heat. While the fluid expands along any isothermal, one of its properties—viz., its temperature—is constant. Similarly we may regard an adiabatic curve as the graphic representation of the fact of some other property of the fluid remaining constant during expansion along that curve. This property we call "entropy," and the adiabatics are sometimes called isentropic curves or isentropics. Just as each isothermal may have a number affixed indicating the corresponding temperature, the isentropics may each have a number affixed indicating the numerical value of the entropy. Just as the state of the fluid when at zero temperature lies outside the range of experimental knowledge, so does its state of absolute zero entropy. However, as it is differences of entropies rather than their absolute values with which we are concerned in thermodynamics, we may take the line $a\,a_1\,a_2 \ldots \alpha$

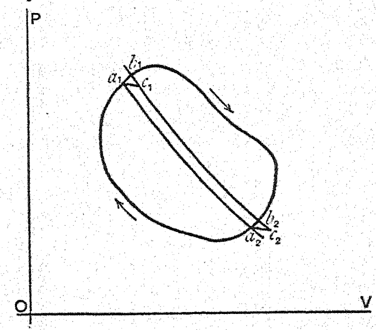


Fig. 41.

as the line of an arbitrary zero entropy. The isentropics $b \ldots \beta$, $c \ldots \gamma \ldots$, $d \ldots \delta$, will correspond to states of the fluid with the entropies in the ratio 1 : 2 : 3.

Let us consider more closely the physical meaning of "entropy" as thus defined. Take any

point, say a_2, in the zero isentropic $a \ldots \alpha$ to represent the initial state of the fluid, and let it expand isothermally to the state d_2 on any isentropic $d \ldots \delta$. Suppose now that the isentropics $b \ldots \beta$, $c \ldots \gamma$, $d \ldots \delta$ are at such a distance apart that each little parallelogram such as $b_1 c_1 c_2 b_2$ corresponds to one unit of heat. The quantity of heat absorbed during isothermal expansion from a_2 to d_2 is then $3t_2$. Similarly the heat absorbed in the isothermal expansion $a_3 d_3$ is $3t_3$. Thus in isothermal expansion from any point on isentropic 0 to isentropic 3, $H = 3t$; H being the heat absorbed and t the temperature at which it was absorbed. The number 3 expresses the value of the entropy for the curve $d \ldots \delta$. Generally, the heat absorbed in isothermal expansion from zero isentropic = entropy of the final state × temperature at which the heat is absorbed, or $H = Et$, *i.e.*, $E = \frac{H}{t}$, t being measured from absolute zero.

In Fig. 41 let the closed curve be the diagram of a reversible cycle. Let $a_1 a_2$, $b_1 b_2$ be two isentropics very close together, then considering the expansion $a_1 b_1$ as equivalent to $a_1 c_1 b_1$, $a_1 c_1$ being an isothermal, and similarly the compression $b_2 a_2$ as equivalent to $b_2 c_2 a_2$, it is easily seen that the gain of entropy during the expansion $a_1 b_1$ is equal to the loss of entropy during the compression $b_2 a_2$. Dividing up the whole area of the closed curve by isentropics we see therefore that in a complete reversible cycle there is no gain or loss of entropy.

WATCH AND CLOCK MAKING.—V.

By David Glasgow,

Vice-President of the British Horological Institute.

[*Continued from p.* 228.]

CHRONOMETER AND WATCH MAKING (*continued*).

Motion Work.—The finisher is now supplied with the motion wheels, and when the centre wheel is planted, a proper depth can be made with the cannon pinion and the minute wheel. The stopping for the centre wheel is left projecting and should be turned in the mandrel into a pipe; the pivot should project well through the hole, and the cannon pinion, having a greater number of leaves than the minute wheel pinion, will be large enough to have a square sink turned out of its face, to free the pipe left projecting. This is the finisher's work, and can only be well done at this stage, as leaving it for the examiner to do after the pinion is polished and the frame gilt is doing the work twice over and doing it badly.

The minute wheel depth with the cannon pinion should be as deep as is consistent with perfect freedom, as should also that of the hour wheel and minute wheel pinion, in order to prevent the hour hand from having too much shake.

As there is seldom height enough for the minute wheel stud to have a shoulder—which it should have where practicable—the plate should not be turned, but a small boss be left on the bottom of the wheel to prevent all of it from touching the plate.

The hour wheel should be broached to the required size, and the cannon pinion fitted to it before the wheel is got true on the sides and finished, as, if the wheel is opened to fit the pinion, it fits badly and it is scarcely possible to keep it true. The body of the cannon pinion should not be left large. The minute wheel stud and pinion, and the boss of the hour wheel should be freed from the dial before they are finished, for nothing could be worse than the prevailing practice of thinning and finishing the motion wheels before they are let into their places, and leaving the freeing and fitting to be done afterwards.

When the third and fourth wheels have been pivoted, before sending the frame to be jewelled, a circle the size of the balance should be marked on the top plate as a guide to the jeweller, as in case the balance comes near the fourth hole, the jewelling must be kept small; otherwise, in turning the edge of the plate to free the balance, the setting will be cut into. It is sometimes better to pivot the fourth pinion a good way into the plate, and obtain freedom for the balance by running it under the jewel hole. All this is of course avoided in a movement of a correct caliber, or in a half-plate movement where the fourth wheel is run in a cock under the balance, this arrangement securing the advantage of permitting the fourth wheel being planted so that a larger seconds piece could be got in the dial. Since, in this case the hole in the cock is directly under the balance, it should have an endstone to prevent particles or small hairs that may be attracted by the oil in the hole from coming in contact with the balance: when the endstone is used, the pivot should be conical, and may therefore be made smaller; but I see no reason why this hole should not always have an endstone where there is room for it.

Screws.—There is seldom as much care taken in hardening and tempering them as there should be; the screws are made too hot before hardening, and a scale brought on the steel that is not always removed before blueing them: in the case of jewel screws, the scale thus left on them is frequently fatal to the taps in the holes. The large screws should be hardened in a small copper box, or in anything that is not large and heavy and will not

prevent them from cooling quickly, and that will exclude the air. If they are hardened at the right temperature, there will be no scale on them and no necessity for polishing the taps: the temper should be drawn in oil. The jewel screws are too small for this treatment: if a piece of brass wire is hammered flat and left the thickness of the length of the screw taps, and a number of holes be drilled and tapped in it as close together as the heads of the screws will permit, half a dozen of them can be screwed into the wire and hardened at the same time, and afterwards tempered by blazing in oil before removing them from the wire; and, if the threads have been covered during the process of hardening, they will be quite free from scale and the screws be ready for polishing. If any scale is left on the large screws it should be removed by gripping the screw head in the Swiss screw tool, and running a thin screw-head-slitting file through the bottom of the thread. A very good way of polishing the taps of screws for best work is to split a piece of wood, making it into claws, charge the slit with red stuff, and by placing the screw in it and pressing it together, the screw can be polished very quickly by working it backwards and forwards with a screw-driver.

Suggestions as to Finishing.—I think at this stage the finisher's work should be completed, and that making and planting the stud and index, springing and examining, and whatever else remains to be done to the watch, should constitute a separate branch of watchmaking.

If the wheels were run in and finished, the barrel and fusee work completed, and the stop work and maintaining-power spring and detent done correctly at once, they would not require to be done over again; and if the motion work were planted and finished and free of the dial, there would be little of the ordinary examining to do, so that fitting the watch in the case, fitting the hands, the stud and index work, and springing and examining, would form an important branch of watchmaking. The practice and experience gained would enable the workman to do the work very much better than it has been done under the system hitherto practised, and to do it quicker and consequently cheaper. The watch could be sprung and examined before it was gilt, and the index, stud, etc., finished while the engraving and gilding were being done. There is an obvious advantage in examining the watch before it is gilt, as gilding has the effect of covering many defects of workmanship, and the greatest advantage this system would have over the usual one would be that of having one person responsible for the correctness of the work throughout.

Applying the Balance Spring.—The size of the spring is the first consideration, and this should not be left to accident; it should depend on the length required, which depends in its turn on the closeness of the coils of the spring. As a general rule, half the diameter of the balance is a good size for the spring, but if the coils are very close, it should be a little less.

If the diameter is marked on the projecting ear of the balance cock that carries the stud, and a notch is cut in it for the spur of the stud, three-fourths of it outside the mark, the spur may be fitted. It should be carefully fitted, without shake, and exactly opposite the balance hole: if it is either too far back or too far forward, the hole for the spring will stand at an angle across it. The stud may be fixed with either a conical or square-headed screw, and it should be cut away to allow of its removal from the cock without taking the screw out, and the screw should be left long enough to permit of this being done easily.

When the stud is screwed into its place, and the end of the spur freed from the arms of the balance, the circle fixing the size of the spring can be marked on it. If the spring collet has been made by the escapement-maker, as it should be, a pivot broach can be put into the hole in it for the spring, and the broach, lying parallel to the balance cock, will indicate the height on the spur where the hole must be drilled; the hole should be drilled with a small drill. As the spring is not circular but spiral, the holes for the curb pins must be drilled inside the circle drawn for the hole in the stud, but how much, depends on the closeness of the coils of the spring, since the farther apart the coils are the more the spirals diverge from the circle, and care should be taken not to place the curb pins too far out, which is often the case, and is a much worse fault than having them too near the centre.

When the hole in the stud is drilled and broached tangential to the spring, if the depthing tool is adjusted so that the point of the centre will mark the inside edge of the hole, and a mark is made on the index at the same distance, the curb pins can be drilled on each side of this mark.

A surer way than this, although giving a little more trouble at first, is to pin a spring in the stud, first moving the spring through the stud hole until the proper size of the spring is indicated by its centre coming over the balance hole; it will be seen if the stud hole is in the right direction, and if not, it can be broached until it is so at this stage with perfect accuracy.

When the eye of the spring is concentric with the balance hole, if the index is placed in the middle of the balance cock, a mark can be made with a very fine point on each side of the outer

coil of the spring for the index pins. These should be very small, especially the inside one, and, if the spring has close coils, a portion of its thickness should be filed away, to free the second coil of the spring; bending the spring for this purpose should not be resorted to if it can be avoided. The pins should be close together, allowing the spring freedom, but as little play as possible, and only just free of the balance arms to prevent the second coil of the spring from getting between them.

The horn of the index should be at such angle that, when the index is pushed over to "slow," it will come close to the stud, as the shorter the spring is between the stud and the index pins, the better the watch will go. If the spring is to be a Breguet, the overcoil will be a segment of a circle, and the pin holes can be marked for with certainty. As the spring occupies only half the hole in the stud, three-fourths of the hole should be outside the point of the depthing tool when it is adjusted to mark the place the spring will occupy on the index, and the holes can be drilled on each side of the mark.

It has become the custom of the Swiss to put Breguet springs to watches that are quite unworthy of them, where no adjustment of any kind is attempted, and the studs and indexes are so badly fitted that these watches must give the worst results to the wearers of them and the greatest trouble to the watch jobbers: the studs are made, for the most part, in the shape used in the best English watches. Now if Breguet springs are to be applied to these watches in this cheap and slovenly manner, the old-fashioned Swiss stud (Fig. 7), that

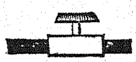


Fig. 7.—Old-fashioned Swiss Stud.

slipped into a notch in the cock, with a head on it, and was kept in its place by a small cap fixed with two screws to the cock, would be a great improvement on the imitation English one. Indeed, this stud is a very good one, as, when the watch is set going, the play of the spring between the index pins fixes the position of the stud, when all that is necessary is to tighten the screws, and the spring will be in the middle of the index pins.

WATCH EXAMINING.

Watch Examining.—Watch examining has been a growing branch of watch manufacturing; with a better system a change should be brought about in this department. If the watch to be examined has a dome case, the examiner has nothing more to do with that, as the fitting is complete. But most English watches have the double bottom case, and are fixed in with a bolt and joint, the bolt and joint, with the motion work, having been made by the motion maker, and the bolt polished, etc., by the finisher. As the finisher has probably had no opportunity of trying the movement in the case, the bolt may not shut in properly, or it may be easily released: it must therefore be seen to, and the joint should be broached out with the bizzle on, and a pin fitted tightly enough to keep the bizzle and movement from dropping back if either or both are raised from the case. The pillar plate should be laid on a piece of plate-glass or other flat surface, to ascertain if it has been bent in the gilding; if it has, it must be got flat, otherwise the pillars will not be upright, and will stick in the holes in the top plate. If the shakes are found to be excessive, this may be due to the gilding having thrown up an edge on the pillars, which prevents the top plate from going down to its proper bearings. In all the best work the finisher fits the cannon pinion to the hour wheel, but this is not the general practice, which is to just let the hour wheel on to the extreme end of the pinion, and not to open the pinion to the set-hand piece, leaving the fitting of these pieces to the examiner. The set-hand piece should be reduced until it fits the centre pinion easily; and before the cannon pinion is let on to its place, it should have the square sink turned out to free the centre wheel stopping, when it should be broached to fit the set-hand piece tightly when in its place.

Fitting the Hands.—If the body of the cannon pinion will not bear turning in fitting it to the hour wheel, the hour wheel should be opened in the mandrel, as it cannot be kept true by opening the hole in the fingers. Fitting the hands to a watch deserves more care and attention than are generally given to it. In fitting the hands, the examiner should fit the glass, if to a hunting case, as high as the case will admit, ascertain the space available by placing a piece of bees-wax on the dial and pressing the glass down on it, and turn the cannon pinion until it projects from the dial the height of the bees-wax; the hour wheel pipe should rise just perceptibly above the dial, and the end-shake of the hour hand be adjusted by the pipe of the minute hand and that of the hour wheel.

If done in this way, the end-shake of the centre wheel will not affect that of the hour hand, which will be always the same, and may be very little, and the minute hand will have a sufficiently long and secure fitting; the hour wheel pipe is always long enough to make the fitting of the hour hand perfectly safe, except where a very thin gold dial is used. The haphazard method of fitting the hands without measuring the room in the case

is a very bad one; they are generally fitted too low, and, with a badly fitting hour wheel, are constantly catching, and so stopping the watch.

As with the hour wheel, the pinion should also be fitted to the minute hand, and not the hand opened to fit the pinion; when the hand is fitted, a little red stuff can be placed on the ball, and the pinion lowered until the red stuff is quite free of the glass, when the end-shake of the centre wheel is pushed towards it; the ball of the hands and the ends of the pinion and set-hand piece are then ready for polishing: this part of the work is usually well done.

Attaching the Dial.—The pin holes in the dial feet should be drilled with a very small drill, in such a direction that the pins will not come in the way of anything, and will be easily got at; they should not be drilled below the surface of the plate, but broached until the pin touches it. If the hole should be a little below the surface, it is better to lengthen the copper foot by squeezing it with a pair of blunt nippers until it is above the plate than to leave it in such a position that no pin can stop in.

General Revision.—The mainspring should be removed from the barrel and the barrel freed on its arbor, if it requires a little end-shake, as it usually does. The freedom should be taken from whichever side of the barrel is nearest the frame—*i.e.*, if the barrel should be nearer the top than the pillar plate, the boss of the cover should be thinned to get the inside freedom, and *vice versâ;* the mainspring can then be put in and adjusted. With the adjusting rod on the fusee square, any fault in the action of the stop work will be seen, and it will also be seen whether or not the chain leads properly on to the fusee. The spring should be set up two or three teeth beyond where it makes an adjustment, as it will give a little, and the set-up be marked on the plate and barrel arbor by a couple of small dots. When the fusee is taken out of the frame, the adjusting rod should be put on the square, and held horizontally with the great wheel in the left hand: if the weight of the rod, which is a measure of the strength of the mainspring, draws the maintaining spring to the end of the notch cut in the great wheel, the maintaining spring will be weak enough, but if not, it must be weakened until it does so. The maintaining power and great wheels must not be pinned on too tightly to the fusee, for if this be so, or if the maintaining spring be too strong, the maintaining power will not act; and the examiner should see to this when adjusting the fusee, and also see that the stop acts properly. The holes for the set-hand and winding squares must be made in the case, or, if they have been drilled, opened to the required size, and the squares reduced to the proper length. The square should be shortened gradually, until a little red stuff on its end does not touch the bottom of the case (the set-hand square may be a little lower), and should be polished either in an English or Swiss screw-head tool; the latter is more convenient for this purpose, especially for the set-hand square; the end should be just a little rounded and the narrow corners be taken off with a very old and smooth pivot file.

The wheels should be put into the frame separately and the end and side shakes of each noted; the depths of the great wheel and centre pinion, and centre pinion and third wheel, can be seen without putting on the top plate; the fourth and escape depths must be tried with the frame together, as they are more important and less easily seen, and, if doubts be entertained as to their correctness, they should be put in the depthing tool and examined. In going barrel watches, the examiner has less work: he should see that the spring is properly free in the barrel, and of a proper length, and not set up so far that it is in danger of pulling the hook away every time it is wound up; the set-square must be kept quite free of the bottom, and it should be fitted very well to the centre pinion, but loose, and, before putting the watch together, a slight dent should be made in the stem with a sharp-pointed punch; this will give it a kind of spring tightness in the pinion which will permit of the hands being easily set, and at the same time keep the minute hand sufficiently rigid.

If the stem is fitted tightly, by polishing, into the pinion to keep the minute hand from being too easily moved, there will be a great danger of it sticking fast: it should always have a little oil put to it to prevent what is termed firing. It will save a little labour, and be a good deal better in principle, to revert to the old plan of a solid centre pinion for keyless watches; by snapping or springing the cannon pinion on the solid arbor, setting the hands is much more easily accomplished, and there is another advantage in having the centre pinion's pivots smaller and stronger.

DRAWING FOR ENGINEERS.—V.

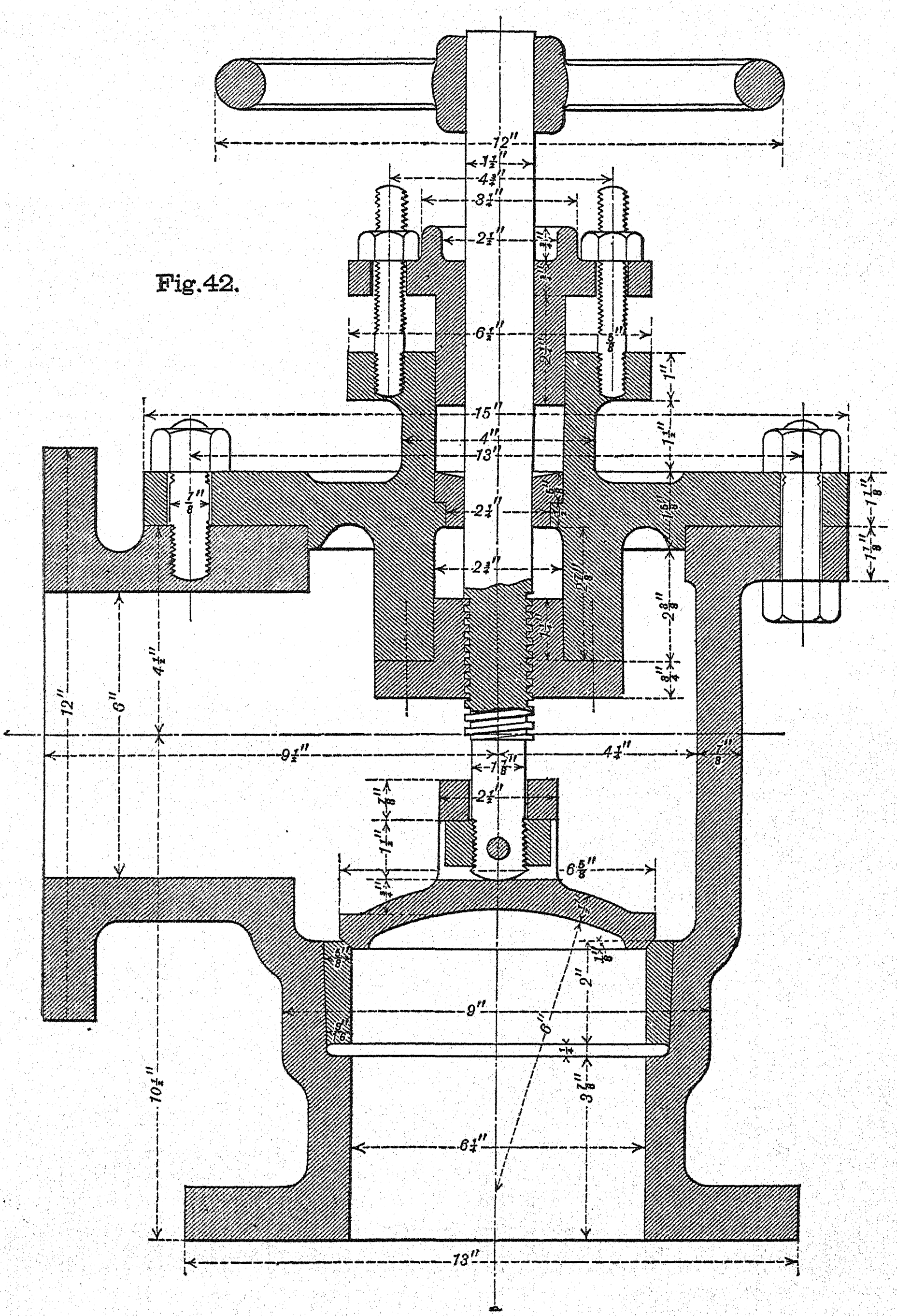
[*Continued from p.* 230.]

PENCIL DRAWINGS (*continued*).

Example 13.—Figs. 42 and 43 *a*, *b*. Section and side elevation of a Stop Valve. Draw half full size.

Example 14.—*Crank-Shaft for Triple Expansion Marine Engine.*—Draw the longitudinal and end elevations to a scale of 1 inch to a foot, and the details of the couplings full size.

Fig. 42.



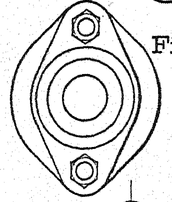


Fig. 43a.

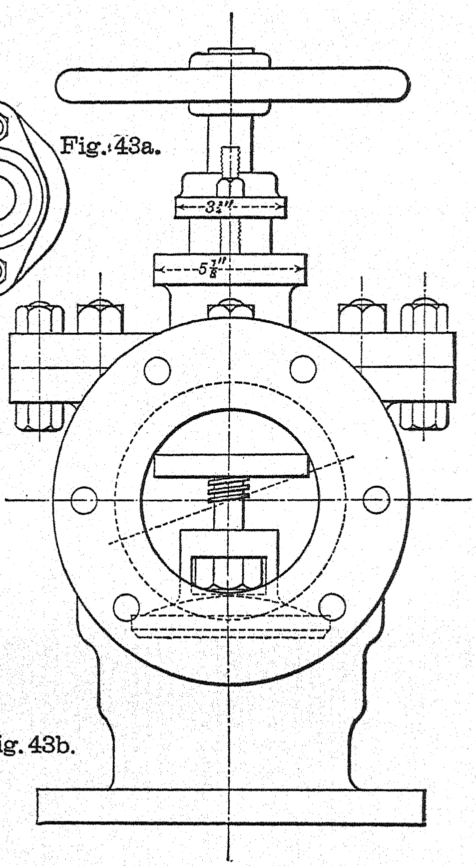


Fig. 43b.

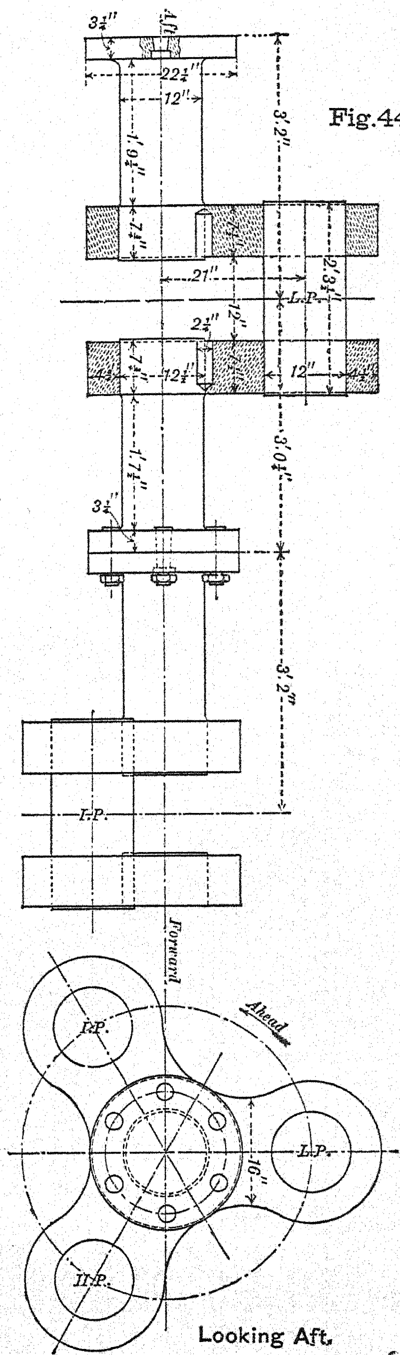


Fig. 44.

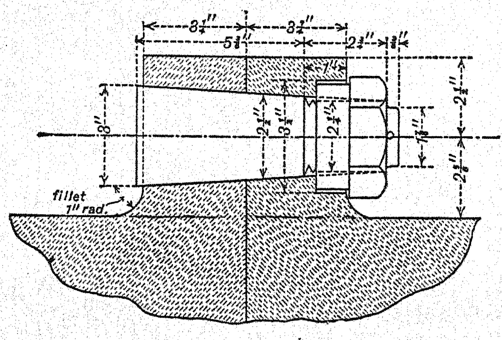


Fig. 45.

This is an example of a "built up" crank shaft in which the component parts are of comparatively simple form, as distinguished from a "three-throw" crank shaft forged all in one piece. The shaft is in six lengths, there are three crank pins exactly similar, and there are six crank cheeks, all alike in general outline. The crank cheeks are fixed to the shaft by round pins driven into holes drilled partly in the shaft and partly in the crank cheeks. Fig. 45 shows in detail the coupling. The bolts are tapered and have no heads, the holes for them are "rymered" out while the two lengths of shaft are held temporarily in their proper relative position. Fig. 44 shows the coupling of the crank shaft in end elevation. No special fastening is required for the crank pins, the crank cheeks being slightly shrunk on them. It will be noticed that in one or two places a small part of the drawing is shown in section, the rest in elevation; the section and elevation being separated by a wavy line. This may be done wherever found necessary for making the method of construction clear.

COLOURING DRAWINGS.

The following are the colours used in engineers' drawings:—

Material.	*Colour.*
Cast Iron	Payne's grey or neutral tint.
Wrought Iron ...	Prussian blue.
Mild Steel	$\frac{2}{3}$ Prussian blue, $\frac{1}{3}$ crimson lake.
Cast Steel	$\frac{2}{3}$ Payne's grey, $\frac{1}{3}$ crimson lake.
Brass	Gamboge with a very little crimson lake.
Copper	Crimson lake.

For the materials mentioned above the colours opposite are almost universally used. For other materials the draughtsman has more choice. The following table may serve as a guide:—

Material.	*Colour.*
Brickwork	Crimson lake, or gamboge and burnt sienna.
Wood	Burnt sienna or burnt umber. A little sepia may be added to these colours. The graining of the wood may be a little darker than the general wash.
Leather	Sepia.
Stonework	Light Indian ink with a little crimson lake.

In inked-in drawings the parts cut by section planes get a wash of colour corresponding to the material.

The colour put on sections should be fairly dark. A little strip at the top and left-hand sides of every surface should be left uncoloured, as in Fig. 46. Were this not done, a black line with dark colour on each side of it would not show up distinctly.

In working drawings it is not usual to colour anything but the part in section. Occasionally, however, a very light wash of the body colour is given to parts in plan or elevation. This light wash should be just sufficient to tint the part to which it is applied, and distinguish it from the rest

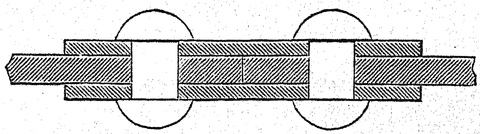


Fig. 46.

of the white paper. Most beginners err by making such light washes far too dark.

In highly shaded and finished drawings the preceding practice is reversed; the parts in section get a light wash of the body colour, and are hatched over with Indian ink lines inclined 45°; while the parts in plan or elevation, after being shaded with Indian ink, receive a dark wash of the body colour.

Before attempting to colour any drawing, the student should practise laying a uniform flat wash of any colour on the paper. Take for the first attempt a rectangle 3″ × $\frac{1}{4}$″, with its long side parallel to the left-hand edge of the drawing-board. The further edge of the board should be raised a little higher than the nearer edge, so that the paper slopes slightly. The brush should be thoroughly moistened with the colour, but should not contain so much that it drops from the brush. Begin at the top of the rectangle, and cover its whole width for a distance downward of, say, half an inch; then do another half-inch of the length of the rectangle, and so on until the whole surface is covered. Above all, avoid giving a narrow strip of colour along the long edge, because by the time the bottom of the rectangle is reached the colour put on near the top will be dry, and as the brush has to go back to the top to complete the width of the rectangle, the part of the paper over which the brush has passed twice will be darker than the rest. In fact, *no partially dried coloured part of the paper must be passed over again by the moist brush*, but any part of the paper having once been moistened must be kept thoroughly moist until the colouring of that part of the paper is completed. If this rule be strictly attended to, with practice a perfectly uniform tint can be given to the paper. The width of the rectangle should be gradually increased for the succeeding trials until a square of three-inch side can be satisfactorily done. Then the space between two concentric circles of 3″ and 2″ diameter respectively may be coloured, taking care to leave the narrow strip at top and left-hand sides uncoloured. In this exercise, begin near the top, work a little towards the left, then to the right, come back again to the left, then to the right again, and so on, never working at one part long

enough to let the colour in another part unfinished have time enough to dry.

Lastly, the colouring of the pattern, Fig. 47, may be attempted. This is rather difficult, and will probably require some considerable practice.

Shading.—An outline drawing conveys to the beginner only an imperfect idea of the object represented. By the judicious shading of some of the surfaces a drawing is rendered much more legible. For example, the plan and elevation of a horizontal cylinder are both rectangles. The plan and elevation of a square prism lying with one face on the ground are also rectangles. So if we were given such a plan and elevation, we would be unable to tell what was represented without the aid of a third end elevation. By shading the surface to represent the distribution of light on it, the form of the object is more easily conceived.

Let us suppose that the rays of light are parallel, and that the plan and elevation of a ray are each inclined 45° to the ground-line. In Fig. 48 the surfaces *a*, *b*, *c* receive an equal amount of light and radiate an equal amount per unit of surface. But the amount of light that reaches a spectator's eye from any object depends not only on the light emitted or reflected, but also on the distance from the spectator. The quantity of light reaching the eye is inversely proportional to the square of the

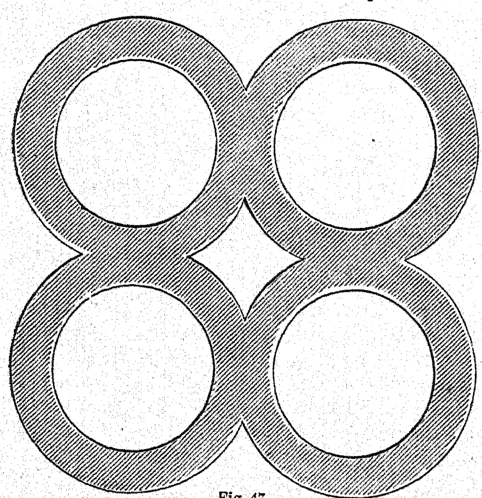


Fig. 47.

distance. Hence in the elevation the surface *c′* will appear to be lightest, *b′* a little darker, and *a′* a little darker still.

In Fig. 49 the surfaces *e* and *f* are both in shadow. When two surfaces are in shadow, that on the nearer surface appears to be more intense

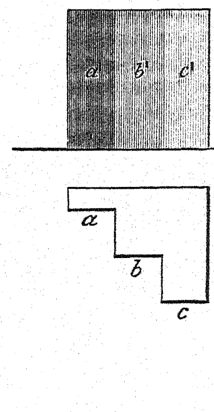


Fig. 48.

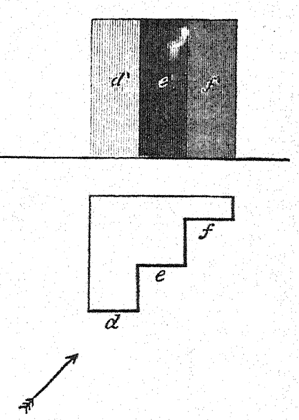


Fig. 49.

than that on the more remote. This proposition will be assented to if we consider two similar bodies one near the spectator and the other further away. On the near object light and shade are easily disti‿guished, but on the further object

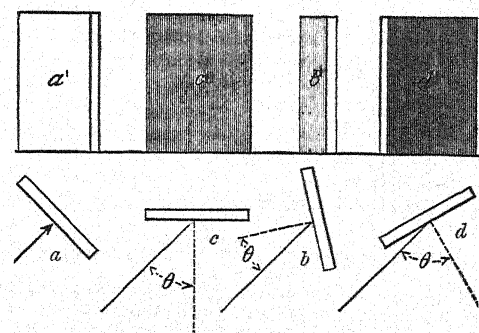
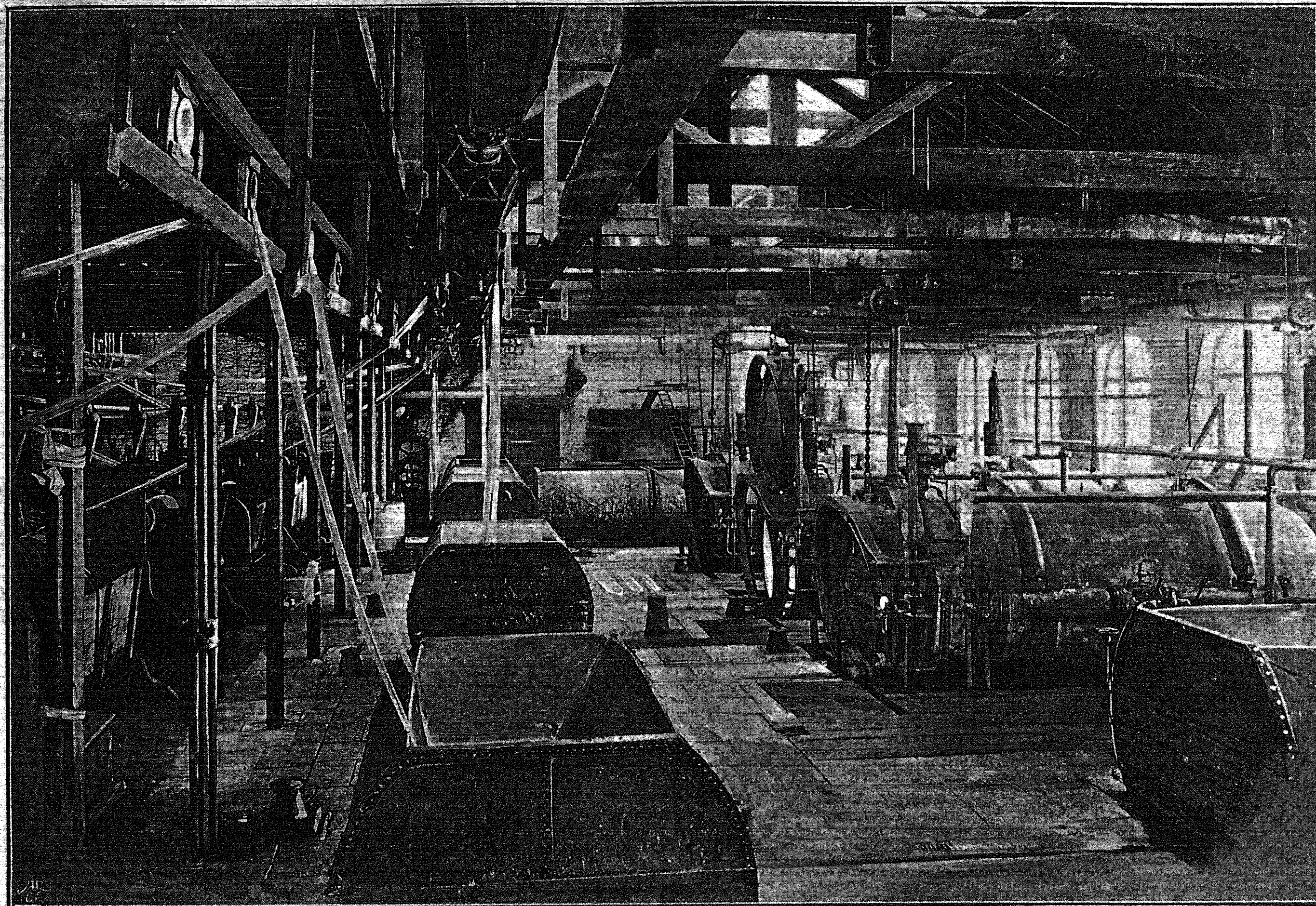


Fig. 50.

the difference is not so marked; that is, the lights are less intense and so are the shadows.

Therefore in the elevation the surface *e′* should be shaded with a darker wash than the surface *f′*.

Again, in Fig. 50, *a*, *b*, *c*, *d* are four surfaces, all practically equidistant from the spectator. The rays of light fall most directly on the surface *a*, less directly on the surfaces *b*, *c*, and *d*. The illumination of the surface is proportional to the cosine of the angle θ between the ray of light and a line drawn at right angles to the surface. Therefore, in the elevation *a′* will be lightest, *b′*, *c′*, and *d′* darker in the order named.



Photograph by Brothers & Co., Manchester.

INTERIOR OF A BLEACHING HOUSE (SHOWING MATHER'S PATENT KIERS).

[MESSRS. EDMUND POTTER & CO., DINTING VALE, GLOSSOP.]

DYEING OF TEXTILE FABRICS.—V.

By Prof. J. J. Hummel, F.C.S.
Professor and Director of the Dyeing Department of the Yorkshire College, Leeds.

[*Continued from p.* 234.]

SILK (*continued*).

41. *Silk Conditioning.*—If raw silk be kept in a humid atmosphere it is capable of absorbing 30 per cent. of its weight of moisture without this being at all perceptible. This circumstance, coupled with the high price of raw silk, makes it of very great importance to those who trade with it to know exactly what weight of normal silk there is in any given lot which may be the subject of commercial dealings. To ascertain this information there have been established in about thirty-seven centres of the silk industry so-called *conditioning* establishments, *e.g.*, in Lyons, Crefeld, Zürich, Bâle, Turin, Milan, Vienna, Paris, London, etc. etc.

Fig. 16 shows the external appearance of the essential apparatus of such an establishment, namely, the desiccator. It consists of an enamelled cylindrical hot-air chamber. One arm of a fine balance sustains a crown of hooks, to which are attached the skeins of silk to be dried. The suspending wire passes through a small opening in the cover of the cylinder. The other arm of the balance carries the ordinary pan for weights.

Fig. 17 gives a vertical section of the chamber. Hot air at 110° C. enters by the tube A from a stove situated in a cellar below, passes into the space B, and thence by thirty-two vertical tubes, *t*, placed between the two concentric cylinders C and D, it enters the upper portion of the inner cylinder D. The hot air descends, dries the silk, and escapes by the tubes E, which communicate with the exit flue. The apparatus is provided with a valve V, actuated by the lever K (Fig. 16) for regulating or shutting off the current of hot air.

The air which passes outside the brickwork of the stove, and is thus heated only to a moderate degree, passes upwards between the cylinders C and D into the space *r*; by means of the button L, which actuates a slide-valve, its entrance into the central chamber can be regulated. By means, therefore, of the lever K and the button L, the supply of hot and cold or moderately warm air into the central chamber can be regulated to a nicety, and the temperature of the mixture is ascertained by the thermometer T. The button S actuates the valve M, which cuts off communication with the exit flue and stops the current of air during a final weighing operation.

Several hanks of silk are taken from the bale to be tested and divided into three lots, in order to be able to make two parallel determinations, and a third if necessary. The weight is first rapidly taken, under ordinary circumstances, on a fine

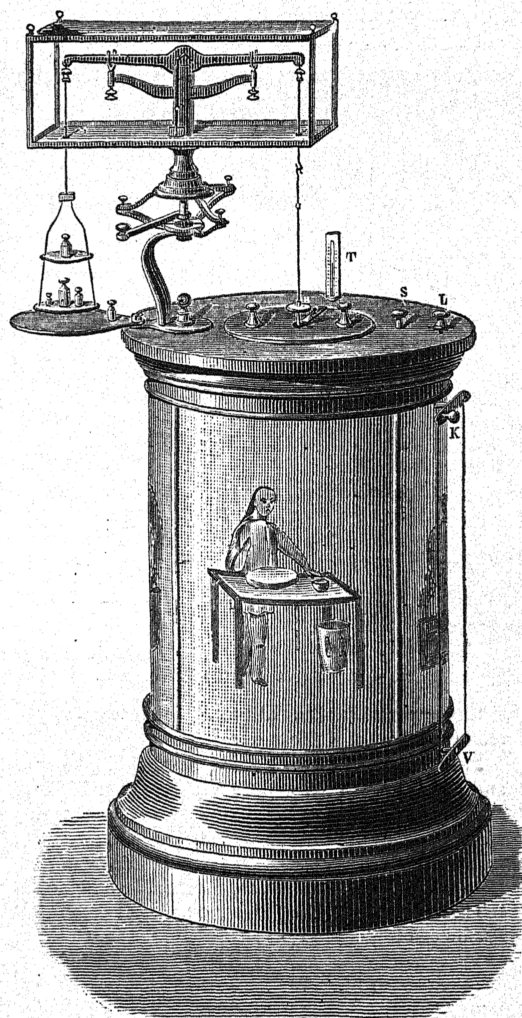


Fig. 16.—Conditioning Apparatus

balance; the hanks are then suspended in the desiccator and counterpoised, and the hot air current is allowed to circulate till there is no further loss of weight. One operation may last from half to three-quarters of an hour.

The average loss of weight usually met with is about 12 per cent. Absolutely dry silk is not reckoned as the standard article, but such as contains about 90 per cent. dry silk and 10 per cent.

moisture. The legal weight is really obtained by adding 11 per cent. to the dry weight.

48. *Chemical Composition.*—The silk fibre is composed essentially of two distinct parts: first, that constituting the central portion of the fibre, *fibroïn*, and secondly, a coating, or envelope, *sericin*, con-

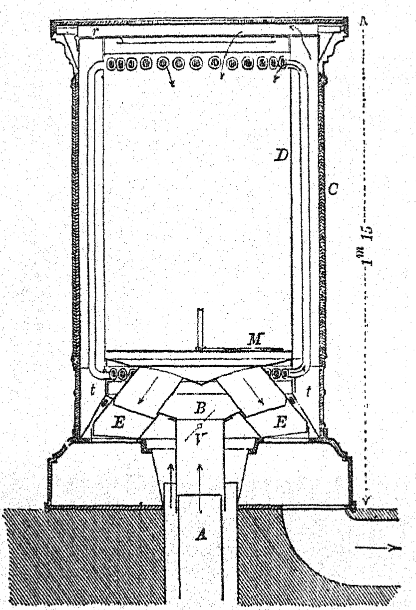


Fig. 17.—Section of Conditioning Chamber.

sisting apparently of a mixture of substances mostly removable by hot water and soap.

Fibroïn.—In order to determine the character and amount of these several substances, Mulder submitted raw Italian silk to the successive action of boiling water, alcohol, ether, and hot acetic acid, and in this way obtained in a comparatively pure state the central silk substance, to which he assigned the name *Fibroïn.* The following numbers give the results of his analysis:—

	Yellow Italian silk.	White Levant silk.
Silk fibre (fibroïn) . . .	53·35	54·05
Matters soluble in water . .	28·86	28·10
" " alcohol .	1·48	1·30
" " ether . .	0·01	0·05
" " acetic acid .	16·30	16·50
	100·00	100·00

Fibroïn is known to be somewhat soluble in strong acetic acid; hence it is probable that what Mulder found to be soluble in acetic acid was altered fibroïn, and that the percentage of this latter substance in silk which he gives is too low.

The usual loss in practice during the operation of "boiling-off" is 25 to 30 per cent., thus leaving 70 to 75 per cent. fibroïn.

The percentage composition of pure *Fibroïn* has been variously stated. Cramer gives the formula as $C_{15}H_{23}N_5O_6$.

Sericin.—That portion of silk which is soluble in warm water can be precipitated from its solution by lead acetate. By submitting this precipitate to a somewhat tedious series of chemical operations it is possible to obtain the essential constituent of the external envelope of the silk fibre as a colourless, odourless, tasteless powder. It swells up in cold and dissolves in hot water. A 6 per cent. solution gelatinises on cooling, and its solutions are precipitated by alcohol, tannic acid, and metallic salt solutions. Altogether, its physical and chemical properties are very similar to those of ordinary glue; hence *Sericin* is often called *silk glue*, sometimes, but more improperly, *silk gum.* Its chemical composition is represented by the formula $C_{15}H_{25}N_5O_8$.

It is distinct from ordinary glue, however, according to some observers, since when boiled with dilute mineral acids it yields other products.

If the formulæ given for fibroïn and sericin be compared, a relationship is apparent which may be expressed by the following equation:

$$\underset{\text{Fibroïn.}}{C_{15}H_{23}N_5O_6} + O + H_2O = \underset{\text{Sericin.}}{C_{15}H_{25}N_5O_8}$$

This comparison has been regarded by some as an indication that originally—*i.e.*, at the moment of secretion, the silk fibre probably consists of fibroïn alone, which, by the action of the air and moisture, rapidly becomes altered superficially into sericin. This view is supported by the observation that if moist fibroïn be left exposed to the air for a lengthened period it becomes partially soluble in water. Bolley and Rosa have found also that the silk-bags taken from living worms are composed almost entirely of fibroïn, since only 1·7 per cent. is soluble in boiling water, and the elementary analysis is consistent with the formula of fibroïn.

Another view, supported by microscopic examination, is that already in the silk-bag both fibroïn and sericin are present, the former being enclosed by the latter.

Influence of Reagents on Silk.

49. *Action of Water.*—Prolonged boiling with water removes from raw silk its silk glue. If heated in a sealed tube with water to a high temperature, the silk is decomposed and entirely dissolves.

50. *Action of Acids.*—Speaking generally, concentrated mineral acids rapidly destroy silk, but if sufficiently diluted their action is insensible. Warm dilute acids, however, dissolve the sericin of raw

silk, and hence these may be used in ungumming (soupling). Concentrated *sulphuric acid* dissolves silk, giving a viscous brown liquid.

Concentrated *nitric acid* also rapidly destroys silk, but if diluted, the fibre is only slightly attacked and coloured yellow, in consequence of the formation of xanthoproteïc acid. This reaction is made use of in distinguishing silk from vegetable fibres. Formerly it was even utilised in silk printing.

Hydrochloric acid, if applied in the gaseous state, destroys the fibre without liquefying it, but a concentrated aqueous solution readily dissolves it.

Sulphurous acid is used in bleaching silk.

Hot dilute *organic acids* remove the sericin from raw silk, but do not materially affect the fibroïn.

51. *Action of Alkalis.*—Concentrated solutions of *caustic soda* and *potash* rapidly dissolve raw silk, especially if applied warm.

Caustic alkalis, sufficiently diluted so as not to act appreciably upon the fibroïn, will dissolve off the sericin, and have been tried as ungumming agents. For ordinary use, however, they must be avoided, since the silk is always left impaired in whiteness and brilliancy.

Ammonia solution, even if used warm, has no sensible action on boiled-off silk.

Alkaline carbonates act like the caustic alkalis, but in a less energetic manner, still they are not employed as ungumming agents. Of all alkaline solutions, those of *soap* have the least injurious effect. When used hot, they readily remove the sericin from raw silk, and leave the fibroïn lustrous and brilliant; hence soap is *par excellence* the agent employed in the ungumming of silk

If raw silk be steeped for twenty-four hours in clear cold *lime-water*, it swells up considerably, the lime seeming to have a strong softening action on the sericin. Prolonged contact with lime-water renders silk brittle and disorganises the fibre.

Chlorine and hypochlorites attack and destroy silk rapidly, and cannot be used as bleaching agents. Applied in weak solutions, with subsequent exposure of the fibre to the air, they cause the silk to have an increased attraction for certain colouring matters.

52. *Action of Metallic Salts.*—If silk is heated with, or even steeped in, cold solutions of certain metallic salts—*e.g.*, of lead, tin, copper, iron, aluminium, etc.—it absorbs and even partly decomposes them, so that less soluble basic salts remain on the fibre. The methods employed for mordanting silk depend upon this fact. Sometimes, as in the case of ferric and stannic salts, the quantity of basic salt which may be precipitated on the fibre is sufficient to serve as weighting material.

An ammoniacal solution of cupric hydrate dissolves silk, the solution not being precipitated by neutral salts, sugar, or gum, as is the case with the analogous solution of cotton.

An excellent solvent for silk is an alkaline solution of copper and glycerine, made up as follows: dissolve 16 grammes copper sulphate in 140—160 c.c. distilled water, and add 8—10 grammes pure glycerine (Sp. Gr. 1·24); a solution of caustic soda is dropped gradually into the mixture till the precipitate at first formed just redissolves; excess of $NaOH$ must be avoided. This solution does not dissolve either wool or the vegetable fibres, and may serve therefore as a distinguishing test.

A concentrated solution of zinc chloride, 138° Tw. (Sp. Gr. 1·69) behaves similarly.

53. *Action of Colouring Matters.* — Generally speaking, silk has a very great affinity for colouring matters. It can be dyed direct with the aniline colours, for example, with the greatest facility.

An examination of sections of dyed silk reveals the fact that the colouring matter (or the mordant) penetrates the substance of the silk fibre to a greater or less degree, according to the solubility of the colouring matter, the duration of the dyeing process, and the temperature employed.

The action of colouring matters on *raw* silk is similar; but in many cases—*e.g.*, in the black dyeing of souples, the colouring matter is situated principally in the external silk glue, which, becoming brittle through the large amount of foreign matter it then contains, breaks up and assumes the form of microscopic beads.

Tussur Silk. —This silk differs from ordinary silk, not only physically, but it is said also chemically. It is less readily acted on by caustic soda, hydrochloric acid, concentrated zinc chloride, etc., and has generally less attraction for colouring matters.

OPERATIONS PRELIMINARY TO DYEING.

COTTON BLEACHING.

54. *Object of Bleaching.*—Raw cotton is contaminated with several natural impurities, which impair the brilliancy of the white belonging to pure cellulose. Hence cotton yarn as it leaves the spinner has invariably a soiled greyish colour. When such yarn is woven it is still further contaminated with all the substances (amounting sometimes to 30 per cent.) which are introduced during the sizing of the warps—*e.g.*, china clay, grease, starch, etc.

Bleaching consists in the complete decolourising or removal of all these natural and artificial impurities.

55. *Bleaching of Unspun Cotton* (cotton wool).—

Cotton wool is only bleached to a small extent, and is then used for wounds, &c., under the name of "absorbent cotton." As a rule, the only treatment previous to dyeing which it receives is that of boiling with water until thoroughly wetted.

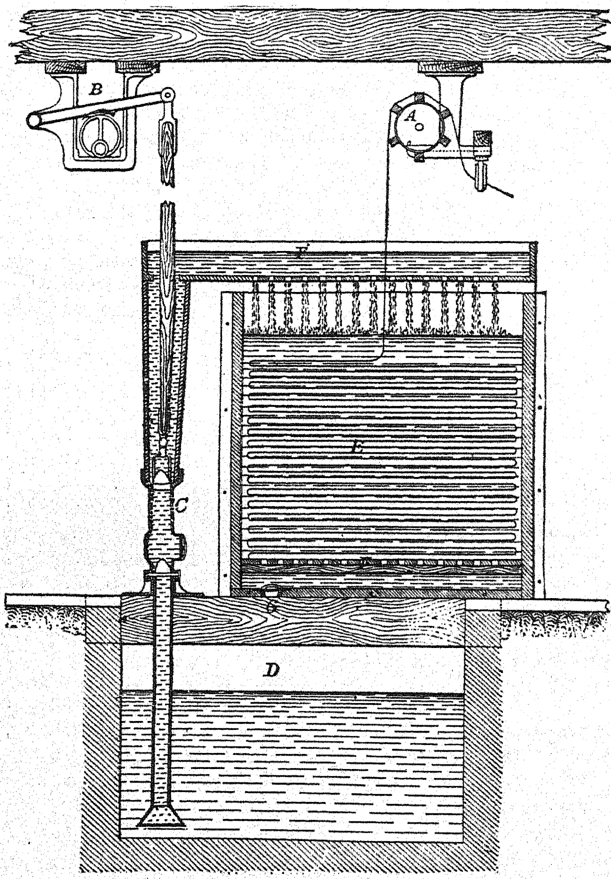


Fig. 18.—Apparatus for Chemicking, Souring, and Washing.

56. *Bleaching of Cotton Yarn.*—For black or dark colours cotton yarn is usually not bleached, but merely boiled with water till thoroughly softened and wetted. For light colours a rapid, but more or less incomplete, bleaching is effected by passing the wetted yarn through a boiling weak solution of soda-ash, then steeping it for a few hours in a cold weak solution of chloride of lime. It is then washed, steeped in dilute hydrochloric acid, and finally well washed.

A more thorough bleaching is that effected by the operations now to be briefly described.

"Warps" are first loosely plaited by hand or machine, in order to reduce their length. If the yarn is in hanks it is either retained in that form, or linked together to form a chain.

(1) *Ley Boil.*—For 1,500 kilos. yarn, boil six hours with 2,000 litres water and 300 litres caustic soda 32° Tw. (Sp. Gr. 1·16); steep in water for forty-five minutes and wash.

(2) *Chemicking.*—Steep the yarn for two hours under sieve in a solution of bleaching powder 2° Tw. (Sp. Gr. 1·01), then wash for half an hour under sieve.

(3) *Souring.*—Steep the yarn for half an hour under sieve in dilute sulphuric acid 1° Tw. (Sp. Gr. 1·005), then wash for half an hour under sieve and afterwards through washing machine.

If the yarn is intended to remain white, its purity is increased by running through a so-called "dumping" machine with hot soap solution and blue (indigo-purple, etc.), then hydro-extracted and dried.

When bleaching cotton thread, owing to its closer texture, the first three operations are repeated.

The ley boil (also called "bowking" or "bucking") takes place in large iron boilers or "kiers."

The usual order of procedure is first to fill the kier with the yarn, and after blowing steam through for an hour or so, to run in the soda solution, and boil for ten to twelve hours.

The operations of chemicking, souring, and washing under sieve, are carried out by means of the arrangement shown in Fig. 18. It consists of a stone tank E, with a false bottom F, and a valve G, communicating with the cistern D below; B is the shaft which works the pump C; F′ is a movable perforated drainer or sieve covering the whole surface of the tank E; A is a winch for drawing the chain of yarn into the tank. Supposing the tank to be packed with yarn, the liquid in D is pumped up to the sieve F′, whence it showers down on the yarn below. It filters through the yarn and collects again in the tank D to circulate as before.

The "dumping" machine referred to is essentially the same in construction as the final washing

machine employed in calico bleaching, the main difference being that the square beater is replaced by a round roller, and that the upper squeezing roller is covered with cotton rope, and rests loosely with its own weight on the lower one. As the cotton yarn, soaked with soap solution and blue, passes rapidly between the squeezing rollers, the irregularities produced by the plaiting or linking impart a constant jumping motion to the upper roller, and the liquid is effectually beaten and pressed into the heart of the yarn, thus enhancing considerably the purity of the white.

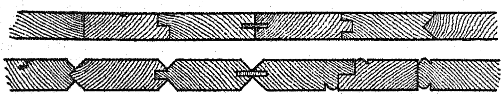
CARPENTRY AND JOINERY.—V.

By B. A. Baxter.

[*Continued from p.* 242.]

DOORS.

Doors form an important part of the joinery of buildings, and are of many different sorts. The simplest and commonest consists of boards held together by being fixed to ledges or horizontal bars by nails or screws. The boards may be rebated or grooved and tongued or matched together; the



Figs. 47 and 48.

joints may be beaded to veil the defects that shrinking may probably cause (Figs. 47 and 48).

The next form of door consists of a frame, of which the styles and top rail are of the thickness required, while any other rails are less by the thickness of the boards which, like the ledged door just mentioned, are nailed or screwed to the rails. This form of door is frequently used for coach-houses, cottages, and school-house doors, and being framed is superior to ledged work. The joints of

Fig. 49.

the boards ought to be rebated, grooved, or matched together, and it ought to be noted that the boards cover the bottom rail. Frequently, in addition to styles and rails, these doors are furnished with diagonal rails, intended to prevent the weight of the door causing it to go out of square (Figs. 49 and 50).

Framed doors consist of styles, the outer upright pieces; top and bottom rails, horizontal rails, whose name indicates their position, and muntins* or inner uprights usually in the centre of the door, and panels or boards to fill the space between the above. The panels of a door may be one, two, four, or more in number. If two, one muntin is required; if four

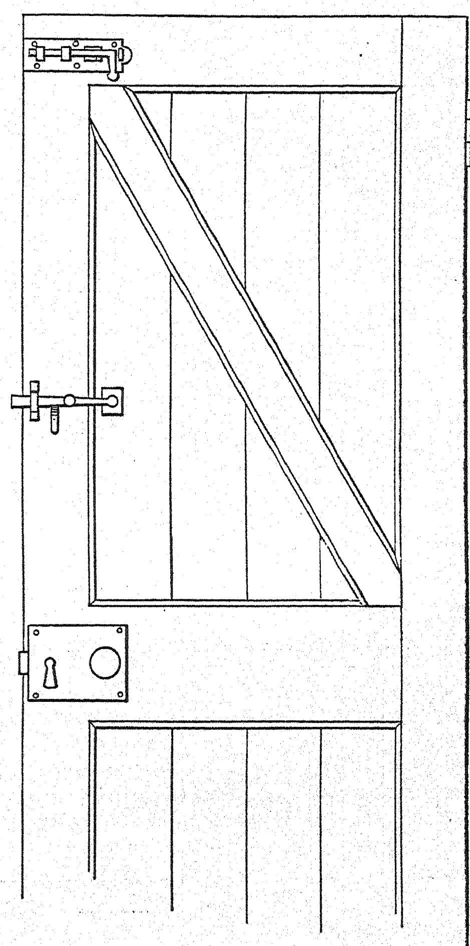


Fig. 50.

panels, then a middle rail and two muntins, and so on. Room doors and entrance doors rarely have less than four panels, though instances occur now and then of a stout mahogany door with only one panel, which, however, in such cases must be as stout as the external frame.

The middle rail is sometimes called the lock rail, and the top of it is generally set 36 or 37 inches from the ground, so that it by no means occupies the centre of the height of the door. Probably the place of the middle rail was thus decided at the time when all rooms of any pretension were lined with

* There is great difference in spelling this word, and various similar words are used, viz., "mullion," "munnion," "munting."

wood in the form of frame and panels, a horizontal rail of some considerable width being placed at that height in order to avoid a thin panel being struck by the tops of chairs. This rail, called the chair rail,

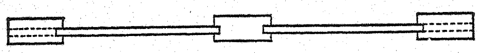


Fig. 52.

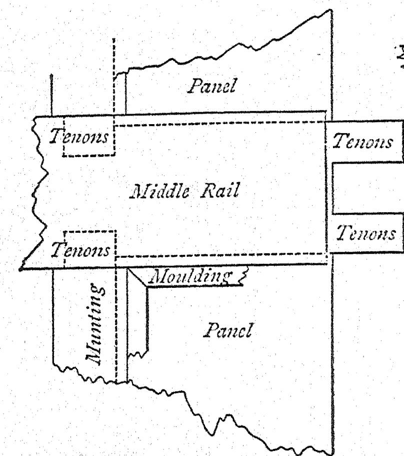


Fig. 51.

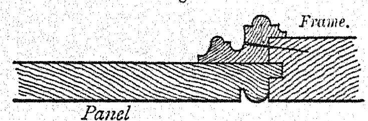


Fig. 53.

would naturally call for a rail at a similar height in the doors (Fig. 51).

The panels of a door or framing are generally, but not necessarily, of thinner material than the frame (Fig. 52). Whenever panels are even or "flush" with the surface of the frame, a bead is

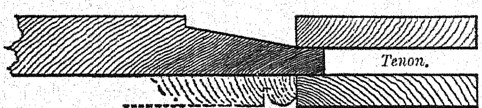


Fig. 54.

worked on the edge of the panel. This description of work is called "bead and butt"; butt, because the ends of the panels "butt" against the rails. If the bead is mitred all round the panel, the term is "bead and flush," and is regarded as superior (Fig. 53).

Panels are frequently reduced at the margin, as shown (Fig. 54), and this treatment can be combined with bead and flush on the other side of the door.

When the moulding is rebated and projects over the edge of the frame, it is called bolection moulding (compare Figs. 53, 54, and 55). These mouldings are frequently bought ready-made; in which case care must be taken that the rebate agrees with the distance from frame surface to panel surface, as it is not easy to alter such a moulding without damaging the front and edges. It is best

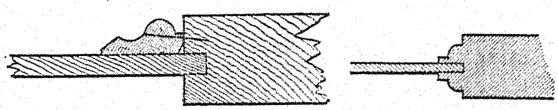


Fig. 55.

to have a sample of the moulding at hand when setting out the doors.

When doors are partly glazed and partly panelled, it is often desirable to diminish the width of

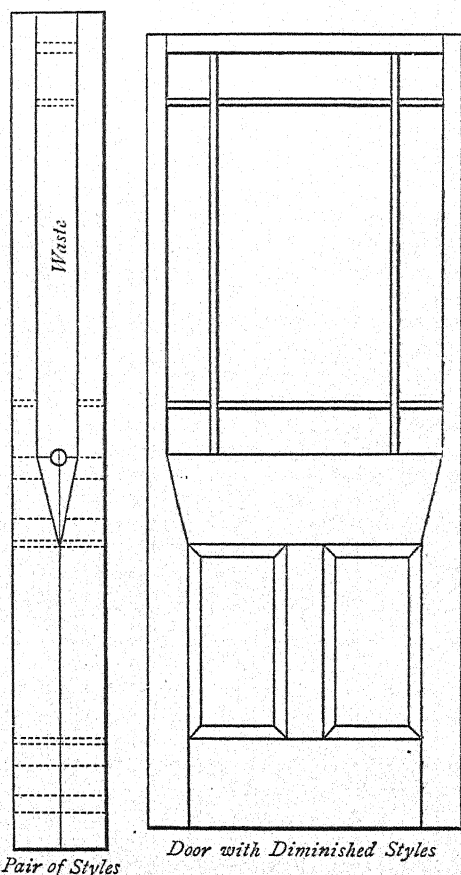


Fig. 56.

the door styles at the upper part which usually contains the glass. When this is intended, it is

usual to prepare the outer edge of the pair of styles straight and true, cutting down at the proper distance from each edge to the top of the middle rail (Fig. 56). When a pair of door styles are thus marked out, the part marked *waste* need not be wasted, though not required for the door. The upper part of the styles will be moulded like a sash, and of course rebated at back for the glass. If the door is to be painted, the sash moulding may be put on separately, thus forming rebate at the same time; but doors which show the wood ought to have the moulding and rebate worked out of the solid. This can be done best with some of the iron sash routers now so

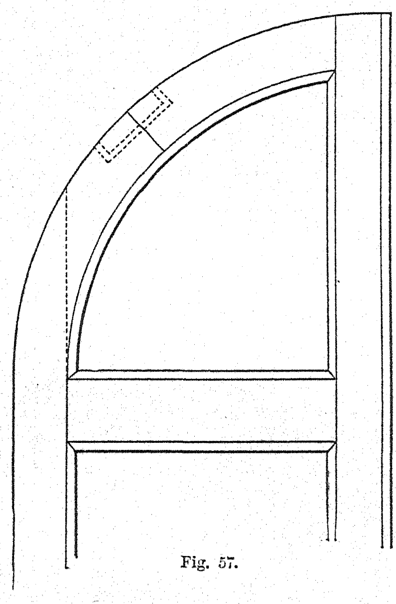


Fig. 57.

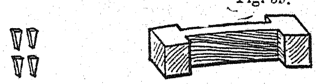
easily procured, and the rebate cut with a similar tool. The mortises must be cut for the middle rail before the splayed joint is cut, although, of course, all the lines will be marked beforehand.

The making of sash bars will be described in the lesson on sashes, but in many cases the moulding will be procured from the moulding mills. The same care to obtain moulding, moulding plane, and router to agree must be exercised as before advised for bolection mouldings, or the mouldings so produced will not intersect with those bought.

Doors with semicircular heads are made in various ways, depending on dimensions, for what would be practicable with a small door would not do for a large one. Some doors, too, for a semicircular head, open in two parts, which is excellent practice, for it is generally better to divide the door, and consequently the weight, than to make one very wide door, or to restrict the opening. The curved top of the door may be built up in segments, joined either by dowels, bolts and nuts, or wooden tongues (Figs. 57–60). The bolts and nuts mentioned will be like those used in hand-rails, having two nuts, one of which is made so that it can be turned with a screwdriver when the parts are brought in contact. The joint should be dowelled as well as joined by the bolt, which ought to be regarded merely as an accessory to draw together a joint that would fit well without it. If the wooden tongue is used it should be made of hard wood, the shape of a letter **H**, thus **I—I**. The central web need not be more than one-fourth the thickness or half the width of the joined rail.

If the doors are to be painted, a thin piece of hard wood, bent and well glued to the edge, will improve the whole; and if beads are used to secure panels or glazing, the fixed bead might be of ash or walnut, and would much add to the strength of the door. Doors that are to be covered will have panels

Fig. 59.



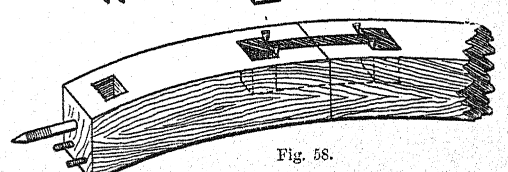


Fig. 58.

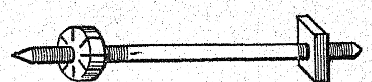


Fig. 60.

flush both sides. If the stuff is not well seasoned the baize or cloth will soon show black lines where the joints have opened and the air passing has left a line of dust to mark the line of joint. Such a door should be covered with brown paper, moistened well and glued round the edges only; if glued all over, shrinking will tear the paper. The carpenter should make a groove on the hinged edge and supply a strip of wood, so that the edges of cloth or baize may be concealed.

The consideration of doors leads to the subject of hingeing. Hinges are a connecting, but flexible, plate, moving on one, or sometimes two, centres, the centre being often a strong wire. Some considerations about fixing hinges may be of value. When two or more hinges are used on a door or flap, it is absolutely necessary that the

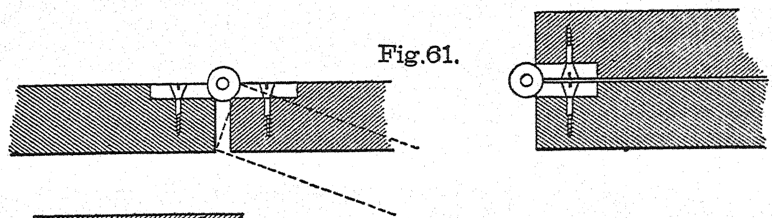


Fig.61.

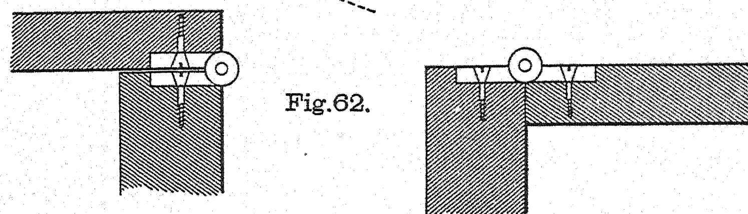


Fig.62.

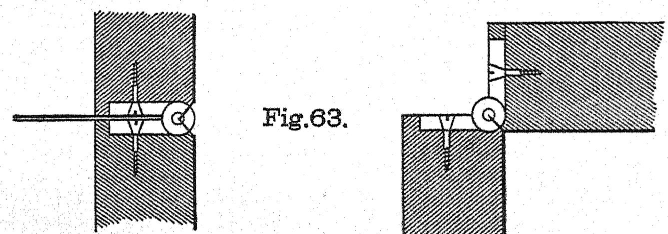


Fig.63.

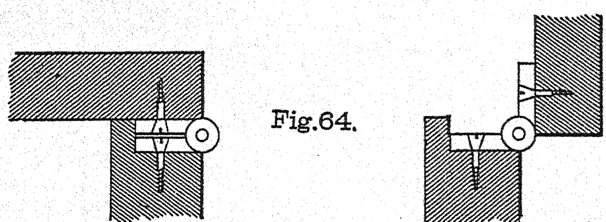


Fig.64.

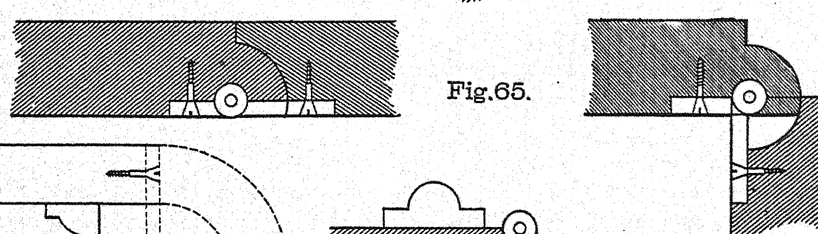


Fig.65.

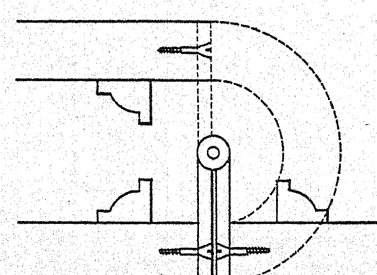


Fig.66.

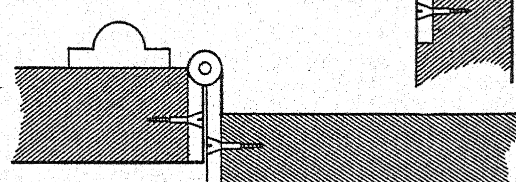


Fig.67.

centres shall be in *one line*. A straight line drawn through the centre pin of one hinge ought to pass through the centre of the others.

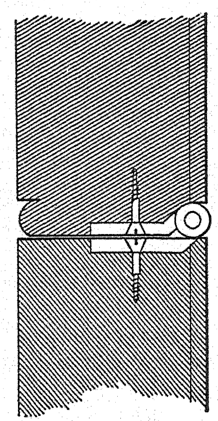


Fig. 68.

With some exceptions, which shall be mentioned, the centre pin ought to be just outside the flap or door (Fig. 61). The flaps shown will close flat together and open out as far as the dotted line, making more than half a revolution. Fig. 62 shows the hinges fixed, so that the centre is exactly at the edge of both flaps, consequently the movement possible is just a semicircle. In Fig. 63 the centre is well within the substances hinged together, and no movement could take place unless the angle had been removed as shown. If the angle is planed off each equally, at 45° and to the right distance, then the movement is limited to 90°. It is not always desirable to cut for the hinges in, say the lid of a box, so that the form of hingeing in Fig. 64

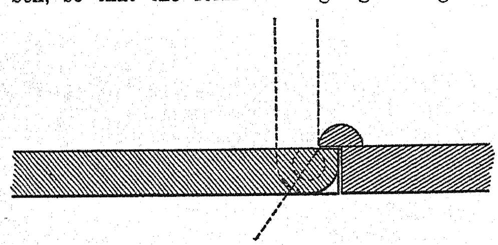


Fig. 69.

is intended to show mode of cutting the whole substance of the hinge into one of the parts to be joined, cutting in, of course, into the part that will hold the longer screws. Fig. 65 shows a joint which used to be very frequently used for shutters and in cabinet work. Inspection of the figure will show that the curves are drawn from the centre of the hinge and that the straight part of the joint is a radius from the same centre. Having the hinges, and drawing the quarter circle from the centre, when hinge is properly sunk, will avoid any error in making this joint. Fig. 66 shows a wide hinge, made for the purpose of avoiding any projection or moulding that would prevent the required movement if narrow hinges were used.

Fig. 67 shows a hinge used when a door or flap is to be at a different surface from the frame; it, too, would allow the door to pass a moulding or projection.

Fig. 68 shows a cranked hinge, intended to allow a bead to be worked on each side of the frame opposite each other, and for the hinge to coincide with the bead, yet to be let in to both door and frame. Figs. 69 and 70 are pivot hinges, drawn to show how to fix them in the right places.

Hinges require careful fixing, and may give trouble in three different ways. The spaces may be cut deeper than necessary, causing the door or

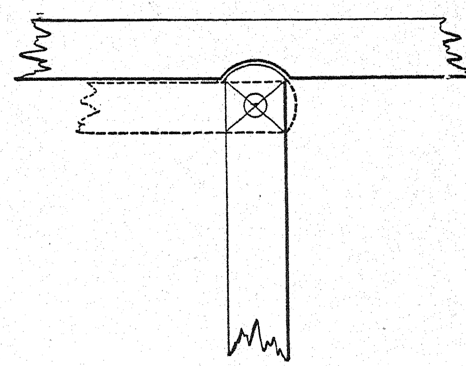


Fig. 70.

flap to be "hinge-bound"; the door may be thicker than expected, and so the back may be too hard upon the stops—it is then "stop-bound"; or it may be that the screws do not fit into the counter-sunk holes, but project, causing the work to be "screw-bound." This last is the worst and most unpardonable sin a workman can commit in hingeing, because it is really so easily avoided. In fact, either of these defects is easily avoided if care is taken, but either fault produces similar effects.

WOOLLEN AND WORSTED SPINNING.—V.

By Walter S. B. McLaren, M.P.

[*Continued from p.* 238.]

WOOL WASHING AND OILING (*continued*).

36. *Verriers Wool-washing*.—So much has been heard in England of the superior wool-washing in Verviers, that the following brief account, given by Mr. Craig-Brown to the South of Scotland Chamber of Commerce, of the washing in the great mill of Messrs. Peltzer and Son, is of value. They are spinners of worsted and woollen yarn made of Buenos Ayres and Monte Videan greasy wool, and very largely supply the Glasgow market:—"Having been sorted, the wool is put into an iron cage mounted on a swivel in front of the first scouring-trough. Here it is saturated from an over-head pipe with a liquor made from the drippings of

previous cagefuls of greasy wool treated with alkali. Pipes carry the drippings into a large tank, where the alkali is added, and the contents pumped

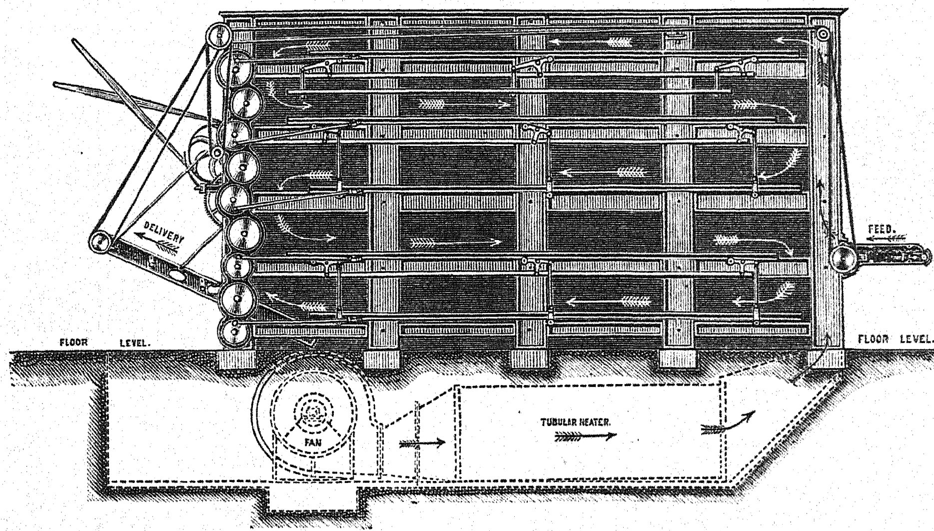


Fig. 7.

high enough to permit of redistribution. This liquor has a remarkable effect in loosening and opening the wool, a process further stimulated in the cage by showers of pure cold water. From this cage the wool is fed into the first tank of the scouring machine; the liquor is the same as with us—soda and hot water. But a feature of the process is the extreme slowness with which the first forks travel—an unquestionable advantage. After being thoroughly raised, or freed from grease, the wool is carried into the rinsing-troughs. These are of great capacity, are kept constantly supplied with a large stream of clean cold water, and have forks travelling at a velocity as much above ours as the forks in the hot tanks are below it, the object of which is obvious. By this radical cleansing the soda is completely removed, instead of being left to eat into and discolour the staple in the process of drying. Most of the wool is 'whizzed' after drying, but I saw one drying-machine fed continually from the scourer, and delivering wool in that nice soft condition—neither too dry nor too moist—which ought to be the aim of every scourer. It was a large hollow chamber, through which the wool slowly passed on an apron, subject to a strong draught of heated air drawn through it by an exhaust fan." It is worth noting here that the scouring property of the potash in the yolk from the fleece is recognised by its being used over and over again to partially wash the new wool, and also that though soda is used for scouring, the wool is well rinsed in clean water lest it should discolour and harden the wool. As much of this wool is dyed before spinning, it is necessary to extract all the oil from the fleece, but potash would do this as well without the danger of spoiling the colour.

37. *Ordinary Hot Blast Drying Machine.*—Having washed the wool, it is necessary to dry it. The common form of dryer is a large flat or sloping table, covered with wire netting, and with wooden sides. Underneath are a number of hot steam-pipes, and at one end is a circular fan which revolves at a great speed, making often 800 or 900 revolutions per minute. The wool is spread on the top of the netting, and the fan blows air heated by the steam-pipes through it, and thus it is dried. Sometimes the pipes are above the dryer, which is then in a small room by itself, and the fan draws the hot air down through the wool; but this mode is much longer and therefore more costly than the former, in which the wool is always being blown up from the wire netting, and thus lies loosely and lightly. In the latter way, the draught forces the wool down on to the netting and makes it lie dead and heavy, so that the air cannot get through it so well. The fault of both dryers is that they take up a great deal of room, and are difficult to cover evenly. Consequently, if any thin place is left, the air blows up or down through it, making the wool

there too dry, and leaving any thick place too wet. There is a risk also of the wool being allowed to remain too long on the dryer, in which case, owing to the hot pipes, it becomes scorched; or it may be taken off too soon, and is thus difficult to work in the next machines. If wool be scorched, it becomes harsh and brittle, and to some extent it loses its colour and becomes yellow. Foreign experiments show that wool, after being absolutely dry, can absorb about 18 per cent. of moisture; but it should never be dried to this extent if it is to be manufactured. Cold-air drying would probably be the best method, but it would take too long, and require too many drying machines to be suitable for everyday work. It is desirable for the sake of the after-processes to retain a uniform amount of moisture in the wool, and this seems to have been effected by the continuous feed and delivery dryer patented by Mr. John Petrie, Junr., Limited, of Rochdale.

38. *Petrie's Dryer.*—Fig. 7 represents one of these machines in a room 20 feet long, 4 feet 6 inches wide, and 14 feet high. The wool is fed in at the side as marked, and passes through, forwards and back again, in the direction of the arrows till it is delivered at the opposite side from that at which it entered, and at the bottom. It rests upon tables which are made of bars lying side by side. Every alternate bar is stationary, the others being movable but fastened together underneath. The set of movable bars have a motion forwards and backwards, but when moving forwards they are *above* the level of the fixed bars, thus propelling the wool forwards with themselves. But when they travel backwards again, they drop down to *below* the level of the fixed bars, and thus do not take the wool back with them. This motion is obtained by the levers and rods fixed to wheels at the front of the machine, as shown in the diagram. As the wool on the top table comes to the end, it falls over on to the next lower, and the same process is repeated. There is a hot blast blowing in the same direction as the wool travels, and this both lightens it and helps it on. It also lifts the wool from the feeding place to the top table, for the entire draught passes the mouth of the opening where the wool goes in. This machine is suited to all classes of wool, long and short. The heat can be regulated as required, and as the wool passes through regularly, every portion becomes equally dry. In an ordinary hot-blast drying-machine, the heat is greatest at the end furthest from the fan, and therefore the wool cannot be all equally dry. Owing to the constant blast of air travelling in the same direction as the wool, the latter is delivered light and open, with no tendency to be matted. The production of dry wool is great, for it is said to be able to dry 80 to 90 packs per week, which is much more than an ordinary open dryer of the same size could do.

39. *Moore's Dryer.*—There is another dryer, however, known as Moore's of Trowbridge, which is extensively used by woollen manufacturers, and which is simpler than Petrie's. As shown in Fig. 8, the machine consists mainly of two sets of small rollers, F F, and a large spiked drum, R. The wool, about 100 lb. at a time, is fed in at C, where there is a door. The lower set of rollers, F, revolve towards the drum, and carry the wool along on the top. They are made of iron tubes $3\frac{1}{2}$ inches in diameter, and fit close together so that no wool can fall, but yet they allow dust and dirt to pass through. The drum is constantly revolving at about 110 revolutions per minute, and as the wool reaches it, the spikes carry it round and up to the top set of rollers, the door, B, being then closed. The top rollers, F, revolve towards the right, and carry the wool to the other end, when it drops down and begins the journey again. There are hot steam-pipes below each set of rollers, and the pipes themselves soon become hot. D D are two chimneys for letting out the hot damp air; fresh air passes in under the lower set of pipes, E. The machine will dry from 1,500 to 2,000 lb. per day. It has the great advantage of being without a fan, which costs much to drive and blows away hot air long before the heat has done its proper amount of work in drying. When the door B is opened the wool is thrown out without any labour.

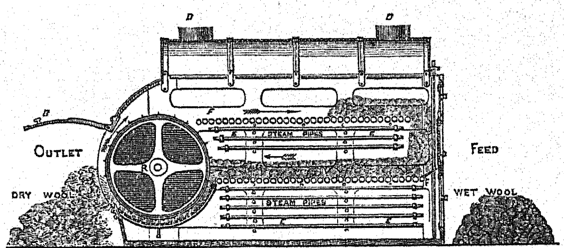


Fig. 8.

40. *Hydro-extractor.*—Where it is possible, it is better to dry without heat at all, simply with a cold blast, because however heat is regulated it is apt to dry the wool too quickly, and so to shrink it and make it hard. Everyone knows that in drying flannel it should be hung in the open air to dry slowly, and not held before a fire or put in a hot place. The same thing, and for the same reason, applies to wool. There is another form of dryer

called the hydro-extractor, which is sometimes used for wool, but chiefly for yarn and cloth, but it does not make them entirely dry. The material is put inside the wire circular cage shown in the centre of Fig. 9, which revolves at an immense speed inside the iron case which is seen outside. It is worked by

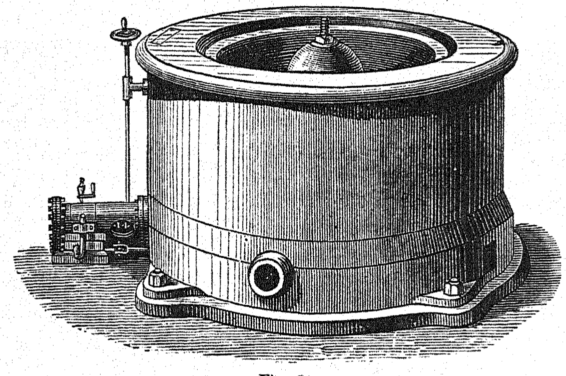


Fig. 9.

the engine at its side. The centrifrugal force and the current of air drive the water out through the sides of the wire cage against the inner sides of the iron case, which is stationary, and it there escapes from a pipe at the side.

41. *Oiling Wool.*—The question of oiling wool is one of importance and interest to the manufacturer, and it is necessary he should use such oils as are best suited to his purpose, if he use any at all. For long English wool, unless it is spun to its farthest limit, oil is really unnecessary either for combing or spinning, but there is no doubt it softens the wool and helps it to spin to a higher count than it would reach if quite dry. But there is another reason why it is liked. It is much cheaper than wool, the very best olive oil being only 5d. to 6d. a pound, while combed wool is cheap when three times that value. Every pound of oil used, therefore, represents a distinct gain to the manufacturer. The French worsted spinners, as is well known, spin without oil, and even when they use it in carding and combing their short Botany wool, they wash it all out before beginning the process of drawing preparatory to spinning. They do this because the cloth can be dyed a brighter and clearer colour when the wool has been worked free from oil and perfectly clean. Some English worsted spinners and manufacturers have adopted the same course, and it is obvious that their customers who scour or dye their yarn or cloth will prefer it free from oil, if for no other reason than that it will lose less weight in those processes when free from than when mixed with oil. If proper care be taken in the working not to destroy the natural oil in the wool, and if the wool be not spun to beyond its proper count, there seems no reason why English spinners should not give up the custom of oiling their wool.

42. *Best Oil to be Used.*—If, however, oil is used for worsted yarns, it should be the best quality of olive. Gallipoli is the name for the very best, but some others are so good as to be hardly distinguishable from it. Olive oil softens the wool, and even after a year or more the wool does not become hard or stiff, and the oil keeps fresh and sweet in it. The loss which may be occasioned by oil turning rancid or sticky on yarn which has been kept in stock for a year is so great that no prudent manufacturer will run any risk; but at the same time, it is most difficult for anyone but an expert to detect adulteration in oil, cotton-seed oil being largely used for adulterating it; and therefore it should only be bought from merchants whose character for honesty can be relied on. A compound known as "soap cream" has been introduced, with the recommendation that it is cheaper and better than oil, improving the colour of the wool, and helping the process of scouring the yarn or cloth afterwards. As, however, it is largely composed of water, its cheapness is not surprising, and its other supposed virtues are very doubtful. The chief result of employing it is that less oil is used than when an equal quantity of real Gallipoli is put on to the wool, and anyone who wishes to arrive at this result had better simply put on half the quantity of Gallipoli and add what quantity of water and soap he thinks fit.

43. *Oleine Oil for Woollens.*—For woollen yarns, especially those containing much mungo and shoddy, oil seems necessary, as the fibre is very short. But as it is all washed out again before or during the milling process, it is not requisite to use anything so expensive as olive, and oleine oil is therefore generally employed. It is obtained from the manufacture of stearine candles. When the stearine is extracted oleic acid is left, but is mixed with sulphuric acid, which has been used to separate the stearine from it. From the oleic acid, oleine is obtained, but the sulphuric acid must be separated from it by distillation. As it is heavier than the oleine, part of it is often left in to cheapen the oil; but this form of adulteration is very injurious, both to the wool on which the oil is used and to the persons working with it. Impure oleine prevents the cloth from dyeing a good colour and makes it streaky; but the pure oil is really of assistance in

helping the scouring of the cloth. One of its properties is the great readiness with which it saponifies, on account of which it is largely employed in soap-works. When, therefore, it has been used on the wool, it is only necessary to put soda or potash into the water for scouring the cloth. The oil comes out of its own accord, and unites with the soda or potash to form soap, and thus scours the cloth. If olive oil has been used on the wool, some soap is needed for scouring. Where woollen yarns, previously oiled with oleine, have to be scoured, it is only necessary to put ammonia into the water, for, being looser, they give out their oil more readily than does cloth.

PRACTICAL MECHANICS.—V.

By R. Gordon Blaine, M.E.,

Assoc. M. Inst. C. E., &c.; Senior Demonstrator and Lecturer on Mechanical Engineering and Applied Mechanics at the City and Guilds of London Technical College, Finsbury.

[*Continued from p.* 247.]

TRANSMISSION OF FORCE BY FLUID PRESSURE—HYDRAULIC MACHINES—ACCUMULATOR—LIFTING MACHINES.

In this lesson I propose to deal with machines in which the force is transmitted, *not* by the contact of solid particles, but by a fluid—such as water. There is usually very little friction in such machines, and the real is nearly the same as the hypothetical mechanical advantage.

Hydraulic machines never fail to excite the wonder of anyone beholding them at work for the first time. The great forces exercised by them, and the silence with which they work, convey the idea of tremendous stores of energy. For instance, if you go to any of the large docks, you will see a boy, by the manipulation of a few handles, raise with ease great loads and deposit them where wanted by means of an hydraulic crane. You will see, in some cases, great ships raised clear out of the water on an hydraulic "grid"; and if you go to the River Weaver, in Cheshire, you will see a portion of a canal with water, boat and all, lifted to a higher level with much more despatch and much less waste of water than is possible with the old and possibly more picturesque locks.

Again, think of the ease with which we now raise great loads by hydraulic lifting machines, as compared with the laborious and tedious processes of our ancestors.

Thus, we are told that 300 years ago Fontana raised an obelisk at Rome with the help of 960 men and 75 horses, working 40 immense capstans. Half a century ago, Le Bas raised the Luxor obelisk in Paris with 10 capstans, worked by 480 men; but fifteen years ago, Mr. Dixon raised Cleopatra's Needle to its position on the Thames Embankment by means of four hydraulic jacks, *each worked by one man.*

In the process of raising weights, therefore, we owe our progress mainly to the introduction and perfecting of hydraulic machinery.

The success of hydraulic machines depends to a great extent on the principle, said to be due to Stevinus, but enunciated by Pascal many years ago in the following words:—"If a vessel full of water, closed on all sides, has two openings, the one a hundred times as large as the other, and if each be supplied with a piston which fits it exactly, then a man pushing the small piston will equilibrate that of 100 men pushing the piston which is 100 times as large, and will overcome that of 99." The reason of this law is evident from a very simple application of the law of work.

Thus, in Fig. 34 two vessels, E and D, are connected by a pipe (and therefore fulfil the conditions of Pascal's *one* vessel) which is filled with water, each of the vessels containing a plunger fitting

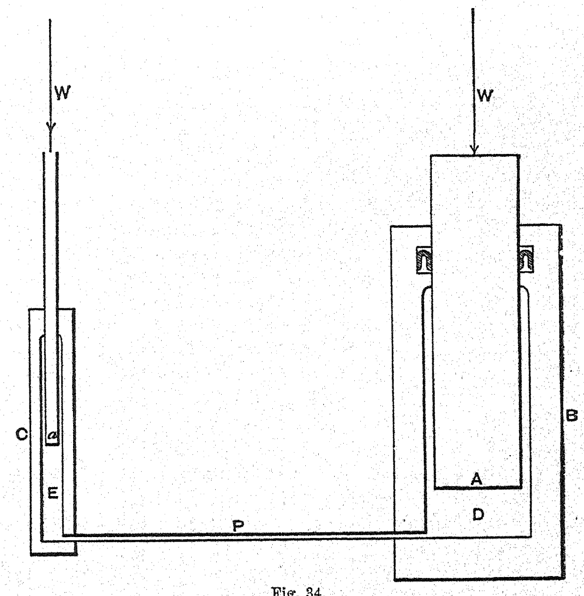


Fig. 34.

water-tight, being also filled with water around and under the plunger. Let the larger plunger be called a *ram*, the larger vessel a press, the smaller plunger

the *pump-plunger*, and the smaller vessel the pump; and you have a diagrammatic representation of the hydraulic press, and indeed of a great many hydraulic machines.

We may assume, for the moment, that water is incompressible—it is very nearly so, being diminished in bulk only about one twenty-thousandth of its total bulk for an increase of pressure equal to one atmosphere; or, if you do not care to make that assumption, then imagine it to be as much compressed as it will be, and, therefore, *no longer changing* in volume. Then, if the area of a right section of the pump-plunger is 1 square inch, the area of the ram being, say, 100 square inches, it is evident that if 100 inches in length of the plunger are forced into the pump, the water displaced must find room for itself somewhere, and if nothing yields or breaks, it will find room by pushing up the ram with whatever load may be on it. How far will the ram be pushed up to make room for 100 cubic inches of water? Evidently, 1 inch; hence, by the law of work, if there is no friction (and there is very little) $P \times 100 = W \times 1$, where W includes the load on the ram and the weight of the ram itself, P being the force actuating the pump-plunger. Hence, $\frac{W}{P} = \frac{100}{1}$ or, generally, $\frac{W}{P} = \frac{A}{a}$, where A and a are the areas of the ram and plunger respectively. This, then, is the hypothetical mechanical advantage of this hydraulic machine; but, taking the pump-handle into account, this ratio would have to be multiplied by the mechanical advantage of the handle to get the total mechanical advantage of the machine.

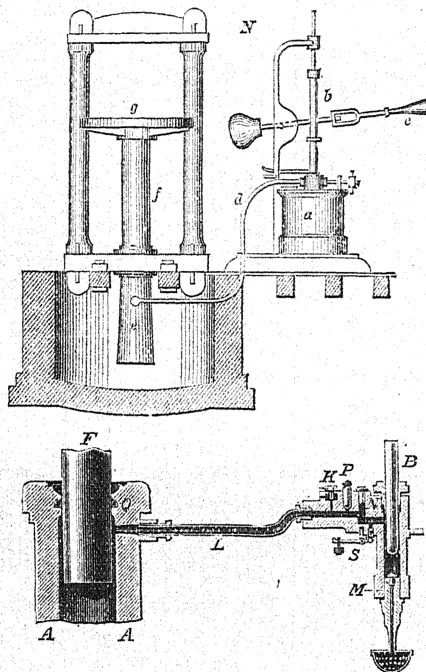


Fig. 35.

HYDRAULIC PRESS.

The hydraulic press, as used in modern warehouses, is shown in Fig. 35. It is a very powerful machine, which owes its success to Bramah, who about the year 1812 took out a patent for the cup-leather packing which surrounds the ram, rendering it water-tight, and thus made the hydraulic press a machine of great practical commercial utility. This leather is shown in Fig. 34, and also in the lower part of Fig. 35; it really consists of a little circular tunnel of leather, fitting a recess in the press and being in contact with the ram. As the water tries to escape past the sides of the ram it gets inside this little tunnel and forces the leather tighter against the sides of the ram.

A section showing the valves, etc., is given in the lower part of Fig. 35, where B is the pump-plunger which in its up-stroke draws in water by the upward-opening valve, M. In the down-stroke, M closes and N opens, allowing the water to pass along the pipe to the press, A, where the ram, F, is lifted by the influx of water from the pump, and thus goods resting on the "platten" or platform, g, are pressed against the top of the framework. The safety-valve, s, allows the water to escape, should the pressure accidentally become greater than a certain amount. A small screw, K, is also provided for the escape of air when the pump is started, together with a plug, P, which can be withdrawn to allow of the pipe L and press being filled with water by hand at the commencement of the operations.

This machine is much used for pressing Manchester goods, in a modified form for expressing oils from seeds, and many other similar purposes. With a machine of this kind two men working the pump can crush into shapeless masses great blocks of oak or concrete; and even large cubes of glass are with ease reduced to fine powder.

THE HYDRAULIC LIFTING-JACK.

This most useful and portable machine for raising loads directly is now much employed, having almost completely displaced the older and less efficient screw-jack. The jack is shown in Figs. 36 and 37, Fig. 36 being an older and Fig. 37 a newer form of the jack. In Fig. 36, H is the spindle to which the handle is applied, the pump-plunger P being, by means of the crank K, raised and lowered by working

the handle. The reservoir C is filled with water, and when the handle and plunger are raised, some of this water is admitted under P by the valve V_1,

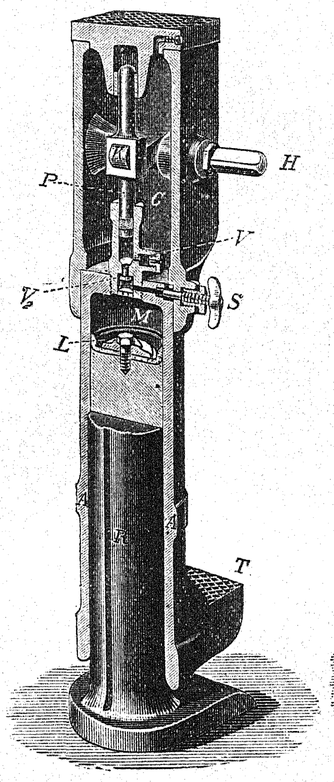


Fig. 36.

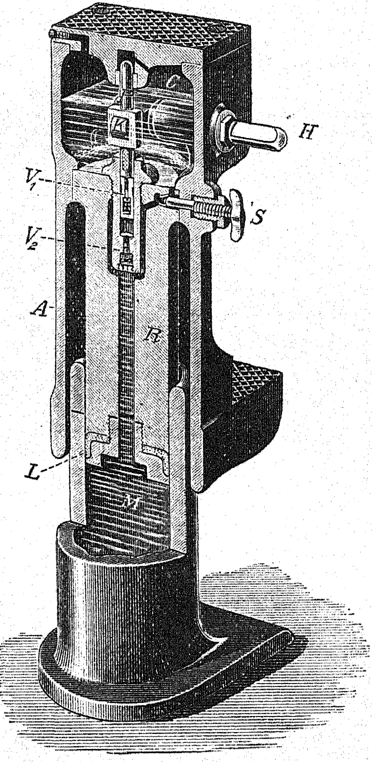


Fig. 37.

which, when P is depressed, closes, the water being forced through the valve V_2, into the space M, above the ram R. The ram is fixed, and as more and more water is forced into M, the casing A of the jack rises together with whatever load may be resting on it. This load may either be applied to the top of the casing directly, as is usually the case, or to the toe, T, of the casing, as in the case where rails on a railway are lifted by this means. S is the lowering screw which, on being opened, allows the water to pass from M back into C, and thus the load is lowered. The groove on the side of the ram fits a projection on the casing, and hence prevents the latter from turning round. A newer form of the jack, shown in Fig. 37, has some improvements. The water passes through the centre of the plunger, which contains the valve V_1, and is forced, on the down-stroke of the plunger, through the valve V_2 and the ram R, into the space M. Then the ram R and casing A are raised as before. It will be observed that in this case the ram is protected from injury, which is not the case in the old form of jack; also the packing-leather L is kept moist more readily; hence, leakage is less likely to occur. If from any cause leakage does occur in the older machine, the water all escapes and the leather becomes hard and dry. The form of the ram in horizontal section is *not* circular, but has a flat side; so the groove is not needed. These and other matters show that the new form is the outcome of careful observation and experience on the part of Messrs. Tangye, who make the machine.

HYDRAULIC TRANSMISSION OF POWER: THE ACCUMULATOR.

I wish now to refer briefly to machines which are worked from a central station which supplies the water at the requisite pressure to all the machines connected with the system.

Referring again to Fig. 34, imagine the press B to receive water from pumps driven by a steam-engine, the ram A having a heavy weight resting on it, and the pipe P being laid under the ground and traversing, it may be, miles of streets, the plunger *a* being the ram of an hydraulic machine such as a hoist, and you have a very fair outline of the elements of an hydraulic system for the transmission of power. When the system was first employed, the requisite pressure was obtained by a "head," or height of water, *i.e.*, water was led by pipes from a reservoir at a considerable height to the machine to be worked. Peter Maurice is said to have been the first to use this method in 1582, his pumps being under the arches of London Bridge, and he raised water to a height of 120 feet for distribution of power. It is easy to see that, to produce anything like the pressures now used, great "heads," or heights, would be required. Thus, consider 1 square foot of area with a column of water h feet high resting on it; it is evident that,

since 1 cubic foot of water weighs about 62·4 lb., the pressure on the square foot is $62{\cdot}4\,h$ lb., or the pressure on each square inch is equal to $\frac{62{\cdot}4\,h}{144}=\frac{h}{2{\cdot}3}$. To produce the pressure of 700 lb. per square inch now used in London, the reservoir would require to be at a height of 700 × 2·3, or over 1,600 feet above the level of the machine worked. Sir W. (now Lord) Armstrong, after using a tower to obtain the requisite height, soon had—to use his own words—"to resort to another form of artificial head" by the employment of an accumulator.

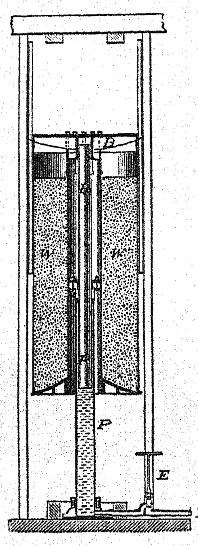


Fig. 38.

The accumulator will be represented by the press, B (Fig. 34), with its ram and weight, and its function is to produce and maintain the requisite pressure in the mains, as well as to afford a storehouse of energy, which will supply any excess above that provided by the steam-engine, which may be drawn on for a short time. It also provides a yielding arrangement in the system, so that if all the driven machines are suddenly and simultaneously stopped, the engines can go on for some time without breaking something, as would be the case if no yielding or flexible arrangement were provided. The accumulator in its usual form is shown in Fig. 38, where P is the accumulator press, R its ram, and W the great weight—of concrete or pig-iron—surrounding and attached to the ram. When the machines are at work the ram and weight of the accumulator are usually either rising or falling; and if not at the extreme bottom of their stroke, but in such a position that the weight rests on water, it is evident that the intensity of pressure of the water must be $\frac{W}{A}$, where W is the weight in lb. and A the area of the cross-section of the ram in square inches. An arrangement is usually provided by which the accumulator weight, when it falls below a certain level, operates a chain and lever and thus starts the engine and pumps, and also, when it rises to a certain height, it in like manner stops the engine. This, then, is an outline of the system. I will now refer briefly to some of the more important of the machines operated in connection with such a system.

HYDRAULIC HOTEL LIFT.

Passenger lifts in hotels, etc., are usually actuated by hydraulic power. The reason of the preference

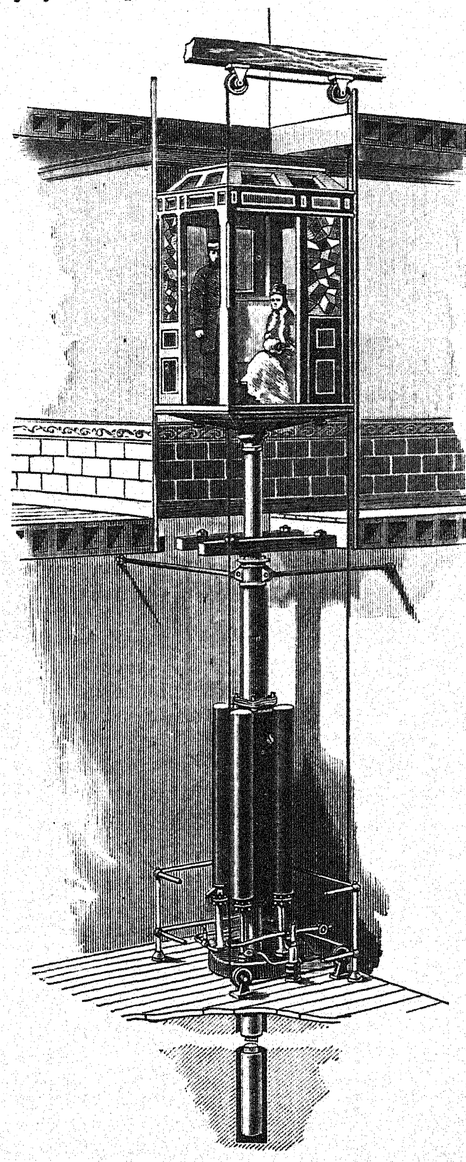


Fig. 39.

for such lifts over those which are worked by chains or ropes is their greater *safety*. If the suspending chains of a non-hydraulic lift break there is great danger of a fatal accident, even though certain safety arrangements, which are intended to come

into use in such an emergency, are provided. There is always a certain amount of uncertainty as to whether these safety-catches will work. A direct-acting hydraulic lift, in which the cage or room is attached to, and rests on, the top of a long ram which works in a corresponding press sunk deep down into the ground, has the great advantage of almost perfect immunity from such an accident, for the ram with its burden always rests on water which cannot escape with infinite rapidity; hence a very rapid descent of the lift is almost impossible. One of the most usual forms of hydraulic lift is shown in Fig. 39, for which I am indebted to Messrs. Tangye Bros., the well-known engineers. The figure requires no explanation, but the reader will notice that it is a "balanced lift." This refers to a matter which I have only space to mention in passing. When any body is immersed in water it loses, or seems to lose, a part of its weight, its apparent weight being less than its real weight by the *weight of the water which it displaces.* Now, when a large portion of the ram is in the press, and therefore immersed in water, its apparent weight is *smaller* than when the lift is well up and the ram is nearly all out of the water. Hence, in order to work the lift steadily, the pressure of water in the mains should *increase* slightly as the lift gets higher and higher in its path, unless there is some variable counter-weight or something which "balances" this increase of weight.

Hydraulic and other methods of balancing are fully described in books dealing with the subject, and I have not space to explain them here. From the foregoing the reader will see that an accumulator does not keep an *absolutely* constant pressure in the mains; but the variations of pressure are, in that case, unimportant.

ELECTRICAL ENGINEERING.—V.

By Edward A. O'Keeffe, B.E.
Senior Demonstrator in Electrical Engineering, City and Guilds of London Technical College, Finsbury.

[*Continued from p. 253.*]

THE DYNAMO (*continued*).

SIEMENS' DYNAMO.

Of those machines in which the drum armature is used, that constructed by Siemens is the earliest and most characteristic type. The general arrangement of armature and field-magnets of this machine is shown in diagram in Fig. 28. As in the Gramme machine, the field is produced by two powerful horse-shoe electro-magnets, E and E_1, which are excited by the current generated in the armature. The poles of these two magnets are brought together so as to form two south poles at the point marked S, and two north poles at the point marked N. The whole of the current generated in the armature is

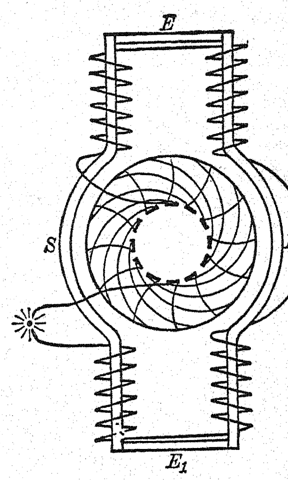


Fig. 28.—Diagram of Drum Machine.

shown as passing round these electro-magnets—in order to excite them to the proper degree of strength—and is then shown as passing into the external circuit, where it is doing useful work. Energy is expended in forcing the current through the armature, field-magnets, and external circuit; and it is clearly of primary importance to expend the largest possible amount of this energy in the external circuit, since the efficiency of working is the ratio of the energy expended in the external circuit to the total energy expended. Since the same current flows through the three parts, the relative amounts of energy expended in each of these parts are as follows:—

In the armature, $C^2 \times r_a$;
" field-magnets, $C^2 \times r_m$;
" external circuit, $C^2 \times R$;

where C expresses the current;
" r_a " resistance of the armature;
" r_m " " field-magnets;
" R " " external circuit.

(The expenditure of energy due to purely mechanical causes is not taken into account.)

The electrical efficiency of the system may therefore be expressed as—

$$\frac{C^2 \times R}{C^2 \times r_a + C^2 \times r_m + C^2 \times R};$$

or,

$$\text{(Electrical) Efficiency} = \frac{R}{r_a + r_m + R}.$$

This fraction is clearly a maximum when r_a and

r_m are as small as possible. The condition that gives the maximum efficiency is to have the *resistance of the armature a little greater than that of the field-magnets, and to have both small compared with that of the external circuit.*

Both the Gramme machine and the Siemens are series machines; but they may also be—and they

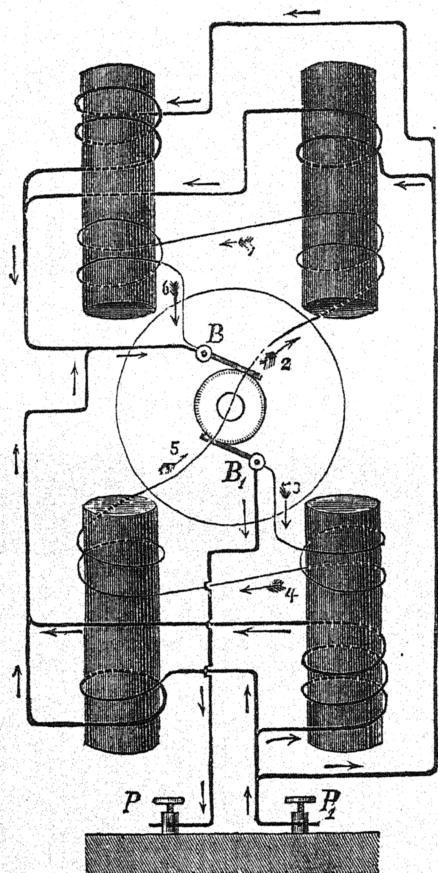


Fig. 29.—Diagram of Siemens' Machine.

often are—wound as shunt machines. In the shunt machine the current, on coming out of the armature, splits into two portions, one of which is utilised for exciting the field-magnets, and the other for doing useful work in the external circuit. The relation between the resistances of the armature and field-magnets, which will make the efficiency a maximum, is now considerably altered; for this machine the condition should hold that—

$$r_m = \frac{R^2}{r_a}$$

(using the same letters as before); and *the resistance of the field-magnets should be at least* 360 *times as great as that of the armature.*

Either with a magneto or a separately excited machine—which is practically the same thing—any change in the resistance of the external circuit produces approximately a corresponding inverse change in the current.

With a series dynamo, a change in the resistance of the external circuit produces more than a corresponding inverse change in the current, since it modifies the strength of the field-magnets.

With a shunt dynamo, a change in resistance of the external circuit produces a similar—but not a proportional—change in the current, owing to the field-magnets being strengthened or weakened as the external resistance is increased or decreased.

With constant speed, none of these machines will give a constant E.M.F. at its terminals, with varying resistances in the external circuit; but a combination of a shunt and a series dynamo will. Constant current is necessary for running arc-lamps in series, and constant E.M.F. for glow-lamps in parallel. Fig. 29 is a diagram of a Siemens machine wound in this manner.

On the commutator rest the brushes B and B_1, from which the current is conveyed to the four field-magnets and to the terminals of the machine, P and P_1. Starting at the brush B_1, the high-resistance shunt circuit—which is composed of many turns of fine wire—denoted by the thin line, is led round the four electro-magnets in series—as shown by following the small plumed arrows—and returns to the armature at the brush B without flowing through the external circuit; the main circuit—denoted by the thick line and the plain arrows—goes to the terminal P, returns from the external circuit to P_1, and then flows through the four electro-magnets in parallel, returning to the brush B. This circuit round the electro-magnets is composed of a very few turns of very thick wire.

The field-magnets thus contain a high-resistance shunt circuit and a low-resistance series circuit, and their strength is due to the magnetising action of both; the part which each of these circuits plays in magnetising the field-magnets can be so proportioned that the machine will supply constant E.M.F., with varying resistance in the external circuit.

The diameter of wire and the number of turns that must be used of each coil will be fully gone into when dealing with dynamo design.

The general appearance of this machine is shown in Fig. 30. The field-magnets are shown standing vertically, but in some of these machines they are placed horizontally, which is in many respects a more convenient arrangement.

The iron of the field-magnets consists of a number of rectangular bars of very soft wrought iron, bolted to an iron yoke at the top and bottom. The central

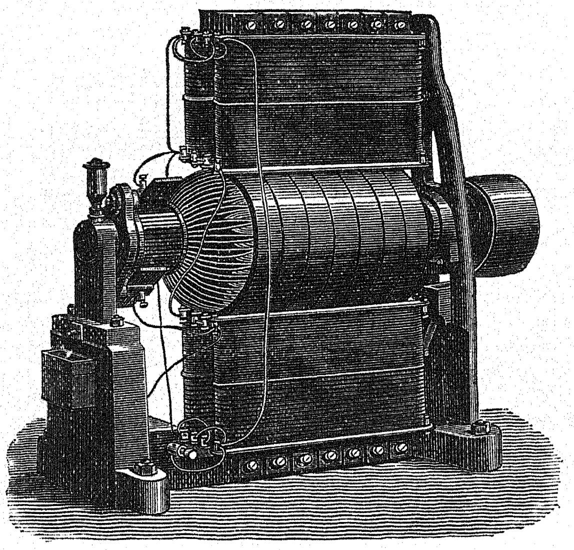


Fig. 30.—Siemens and Halske Compound Machine, producing constant E.M.F.

portion of one of these sets of bars forms a double north pole, and the central portion of the other set a double south pole. The lines of force thus pass horizontally, through the armature, from one of these poles to the other. The core of the armature is not solid, but is built up of a number of thin soft iron discs, which are insulated from one another by paper. This prevents the formation of eddy currents to an undue extent.

FOUCAULT CURRENTS AND HYSTERESIS.

Since the cutting of lines of force by any closed conducting circuit generates currents in that circuit, it follows that currents will be generated, not only in the coils of the copper wire, but also in the core of the armature, which consists of iron, and which, therefore, is a conducting substance. These eddy currents generated in the iron core, and known as *Foucault currents*, play two highly injurious parts in the dynamo—they require an expenditure of energy in order to generate them, which is a waste, and they heat the armature unnecessarily. The heating of the armature increases the resistance of the coils, and produces a further waste of energy there. In Siemens' shuttle-wound armature the massive iron core renders it particularly faulty in this respect. They can be partially avoided by constructing the core of insulated plates, or of bundles of wire, and one of these plans is almost invariably adopted now, notwithstanding the increased cost of construction.

These currents are also formed in the poles of the field-magnets, and notably in the horns. When a dynamo has been running for some time, it may be noticed that the horns become heated owing to the formation of eddy currents, and further, that the leading horn becomes more heated than the trailing one.

Where the dynamo is used for the generation of very large currents, it becomes necessary to use correspondingly large conductors for the loops on the core. In the early days of dynamo construction these large conductors were made of solid copper, and it was found that they became unduly heated for the quantity of current which they were supposed to be carrying. It is now recognised that this extra heating was due to the existence of eddy currents formed in their substance, and that it could be prevented by constructing the conductor of a number of smaller wires joined in parallel, which would have jointly the same sectional area as the original conductor, but which would be insulated from one another. A very light insulation is all that is required, and some makers only insulate the alternate wires—a device which saves labour and answers all practical purposes.

Another cause of the heating of the armature is the fact that the polarity of the core is reversed twice during each revolution; and owing to this fact, by a phenomenon known as hysteresis, a certain amount of energy is expended in the change, and subsequently takes the form of heat. Hysteresis is a kind of molecular friction which must be overcome in order to magnetise or demagnetise any substance. It increases with the intensity of magnetisation, but is not proportional to it, and it also increases as the speed of reversal of the magnetism in the substance is increased; to keep it small, these should therefore not be large. In order to overcome both these heating difficulties, the armature core might be made up of thin insulated plates, the laminations being in the direction of rotation and of the lines of force; it might also be built up of wires, but the resistance of the magnetic circuit might thereby be increased, and the number of lines of force passing through the coils be thus diminished.

The effect of subdividing the iron core of the armature can be most forcibly impressed by considering the actual figures obtained in the testing

of a Brush dynamo designed for running sixteen arc-lamps. In the first case the core of the armature consisted of a solid iron casting with a number of grooves which partially prevented eddy currents, and in the second case the armature was built up of wrought-iron ribbon conveniently bound together. (Both these types will be illustrated and fully described when dealing with the Brush dynamo. It may be mentioned that the cast iron was the original form of the armature, and in the smaller machines is still retained; but in the larger dynamos the newer form is used.) In the two cases the field-magnets and winding on the armatures were identical, the sole difference between the two dynamos consisting in the difference between their armature cores.

An armature with the old form of core could not be run at a speed over 800 revolutions per minute without undue heating, and at that speed it would give a current of 10 amperes and an E.M.F. of 730 volts. At the same speed the new form of armature gave 10 amperes and 1,020 volts. The old armature absorbed 17 horse-power, whilst the new one took only 16. The power obtained from each armature per horse-power expended in driving it is therefore:

From the old cast-iron type . . . $\frac{730 \times 10}{17}$, $= 429{\cdot}4$ watts per H.P.

From the new laminated type . . . $\frac{1{,}020 \times 10}{16}$, $= 637{\cdot}5$ watts per H.P.

And since one horse-power $= 746$ watts,

the efficiency of the old type . . . . $= \frac{429{\cdot}4 \times 100}{746}$ $= 56{\cdot}2$ per cent.;

the efficiency of the new type . . . $= \frac{637{\cdot}5}{746}$ $= 85{\cdot}5$ per cent.

The difference between these two efficiencies obtained from two machines in which the cores of the armatures alone were different cannot fail to impress the importance of thoroughly laminating the armature core, so as to avoid eddy currents.

The higher efficiency was no doubt partly due to the improving of the magnetic circuit by substituting wrought for cast iron; but it was principally due to the avoidance of Foucault currents and unnecessary heating.

THE MAGNETIC CIRCUIT.

The E.M.F. generated by the cutting of lines of force is independent of the resistance in circuit, and depends only—with a given armature—upon the speed of rotation and the strength of the field, and is directly proportional to both. It is therefore desirable to provide as strong a field as is possible, and to provide it at the smallest possible cost.

The field might be provided by permanent steel magnets, which, after the initial expense, require no further expenditure to keep up their strength; they are, however, far weaker than electro-magnets, and consequently any machine in which they are used must of necessity be correspondingly larger than one in which electro-magnets are used, in order to do the same amount of work; besides, the strength of a steel magnet is uniform, whilst that of an electro-magnet is variable, though perfectly under control. The electro-magnet requires an initial expenditure of energy to excite it, and a constant expenditure to maintain that excitation; but the intensity of field which can be obtained by its use far more than counterbalances this unavoidable loss.

The strength of the field is measured by the number of lines of force that pass through one square centimetre of cross-section; where one line passes per square centimetre the field is said to be of unit strength. Any magnetic substance, such as iron, nickel, etc., placed in a field will have lines of force passed through it, and will have more lines per square centimetre than had passed through the original space. This property, possessed in varying degrees by all magnetic bodies, is known as *permeability;* the lines pass with greater facility through such substances than they do through air, a vacuum, or any non-magnetic substance; in fact, these substances are more permeable to lines of force than air. The coefficient of permeability of any substance is the ratio of the number of lines that would pass through that substance to the number that would pass through a similar quantity of air. It is usually known by the letter μ; then—

$$\mu = \frac{\text{B}}{\text{H}},$$

where B expresses the number of lines per square centimetre passing through the substance; or, the magnetic induction,

and H expresses the number of lines per square centimetre passing through air; or, the magnetising force.

This quantity, μ, varies for each substance, and even for the same substance it is not a constant, but changes for each degree of magnetisation to which the substance is subjected. A thorough knowledge of these two quantities, B and H, forms the basis of dynamo design; and during the past few years much good work has been done by Bidwell, Rowland, Hopkinson, Ewing, and others on this subject. The highest values obtained for B with

wrought-iron were, according to Bidwell, 19,820 lines per square centimetre. Rowland gives 16,600, Kapp 16,740, Hopkinson 18,250, whilst Ewing has succeeded, in exceptional circumstances, in obtaining 40,000.

TECHNICAL EDUCATION:

IN THE COLONIES.

By H. W. Just.

In the large self-governing colonies—in Canada, in Australasia, and at the Cape of Good Hope—what has been done in the way of promoting technical education may be conveniently grouped according to these three natural divisions, but space will only permit of a brief statement of the salient facts with regard to each Colony. In these Colonies, as in the United Kingdom, the beginnings of technical education as such are comparatively recent.

CANADA.

By the British North America Act of 1867 constituting the Dominion, education in Canada is left entirely in the hands of the Provincial Governments.

The Provinces of Ontario and Quebec (formerly Upper Canada and Lower Canada) contain the larger part of the population and the chief manufacturing centres, and in the first of these two Provinces the most systematic provision is made for technical education. Drawing has been compulsory in the primary and high schools of Ontario since 1885, and also in the primary schools of Quebec, but no special manual instruction has been introduced in either Province.

Ontario.—The Ontario School of Art, under the direction of the Provincial Minister of Education, aims at preparing teachers of industrial drawing in public and high schools, mechanics' institutes, and art schools; and also at providing technical instruction for those employed in the trades and manufactures requiring artistic skill. The art schools (organised and managed by the Education Department since 1885), the mechanics' institutes, as well as the various high schools and colleges, present a large number of candidates for examination in primary, advanced, and mechanical drawing.

The Ontario School of Practical Science, affiliated to the University of Toronto in 1889, has five regular departments, in which diplomas are granted, viz., civil (including mining) engineering, mechanical and electrical engineering, architecture, analytical and applied chemistry, assaying metallurgy and mining geology. Other university colleges are the Victoria University (Wesleyan); Queen's University, Kingston (Presbyterian); the College of Ottawa (Roman Catholic), which have scientific courses of study (including the applied sciences) and are empowered to grant science degrees. At Woodstock, one of the constituent colleges of McMaster University (Baptist), a manual training department has been instituted, with the necessary workshops, machinery, and other appliances.

The Ontario Agricultural College and Experimental Farm, the best institution of the kind in Canada, well organised in all respects, was established in 1874, near the city of Guelph, the farm consisting of 550 acres, about 400 of which are cleared. At the end of a two years' course of study a diploma is granted. Students of a certain standing and proficiency may remain for a third year. The college became affiliated in 1888 to the University of Toronto, which grants the degree of Bachelor of Science in Agriculture, on examination, to students of the third year. Students consist of the sons of farmers from seventeen to twenty-three years of age. They are required to work in the outside departments—farm, livestock, gardens, carpentry shops—and in experiments. The model farm challenges comparison in America for the variety and excellence of its stock for breeding. There is ground for field experiments, and instruction is given in horticulture, including grafting, budding, etc. The net expenditure on both college and farm is about £8,000 a year.

Quebec.—In the Province of Quebec the Council of Arts and Manufactures directs evening schools in Montreal, Quebec, and other centres. The subjects of the classes held, *e.g.*, in Montreal in the session 1889–90, were freehand, mechanical, and architectural drawing, lithography, modelling and wood carving, decorative painting, stair building, pattern-making, plumbing. Promising pupils frequently go on to Paris.

Three small agricultural schools exist at St. Ann, Richmond, L'Assomption, which are not popular with the farmers; there is no organised central school like the Ontario Agricultural College at Guelph. A separate experimental station has been established at St. Hyacinthe.

At the McGill College and University, Montreal, the faculty of applied science provides a thorough professional training, extending over four years, in civil and mechanical engineering, mining engineering and assaying, practical chemistry, and electrical engineering, leading to the degrees of Bachelor of Applied Science, Master of Engineering, and Master of Applied Sciences. For the session 1891–92 there were seventy-five students in applied science and ten partial students.

To the Laval University (Roman Catholic) was affiliated, in 1887, the Montreal Polytechnic, founded in 1873, which has a three years' course

and grants a diploma in engineering. Its special object is to impart scientific and technical instruction necessary in the professions, particularly the engineering profession (including surveying, bridge and road construction, etc.).

In *Nova Scotia* half the scholars on the register in the common schools are taught drawing, and a summer school of science is held for teachers for a fortnight. The Victoria School of Art and Design at Halifax has an attendance of about 100 students, and at Truro a provincial school of agriculture has recently been started.

In the other Provinces no special attention has as yet been devoted to technical education, and the same is true of the Colony of Newfoundland.

Experimental Farms.—To promote the success of Canadian agriculture the Dominion Government has supplemented the provincial institutions by establishing a system of experimental farms throughout the Dominion which are available for tests and for all kinds of experimental work, but do not take pupils. The Central Farm of 500 acres, just outside Ottawa, is a complete trial farm with all arrangements of the newest type. The director of this and of the other experimental farms resides here, as well as the agriculturist and dairy commissioner, the entomologist and botanist, the chemist, the horticulturist, and poultry manager. All those who are on the staff are utilised as lecturers at agricultural meetings throughout the country, and their work is thus largely educational. There is a well-equipped laboratory for the whole range of agricultural experiment, its results available free of charge, and a museum. The other Government experimental stations are at Nappan, Nova Scotia, for the Maritime Provinces; at Brandon for Manitoba; at Indian Head for the North-West Territories; at Agassiz for British Columbia. Several travelling dairies, provided by the Dominion Government with lecturers giving practical demonstrations as to milk-testing and the manufacture of cheese and butter, are at work throughout the Provinces.

AUSTRALASIA.

New South Wales.—In this colony, perhaps more than in any other, the grading of technical education from the lowest step upwards has been acknowledged as the object to be aimed at, public opinion having been stimulated by the elaborate and useful reports of Mr. Combes, and taught not to rest satisfied with anything less than a thoroughly organised system. In November, 1889, a separate Technical Education Branch of the Public Instruction Department was instituted in place of the previously existing Technical Board. The course of study and standard of proficiency for primary schools were carefully revised, and additional provision made in them for systematic preliminary instruction in kindergarten, drawing, agriculture, manufactures, etc. Steps were also taken to improve the practical training of boys in gardening, bee-keeping, and the use of ordinary tools; of the girls in sewing and cookery. Thus, the circular to public school teachers of April 21, 1890, enjoining upon them the need of giving thoroughly practical lessons in agriculture and horticulture, says: "It is therefore proposed to set apart a portion of the playground for the formation of flower and vegetable gardens, and, where practicable, for the keeping of bees. The planting of fruit or shade trees, the cultivation of grain, etc., or of live fences, and the erection of bush-houses, are matters that could be well taken up. The work should be done by the children, under the direction and supervision of the teacher." This is in keeping with the observance of Arbor Day—a festival widely celebrated in May throughout Australia as well as Canada—representing our school picnics, but with the addition of a beautiful practical ceremony.

According to the reports for 1891, manual training classes were in operation in two schools with highly satisfactory results. There are cookery classes in public schools with 550 students, and 740 learn shorthand. Drawing and needlework are well attended to.

The work of the Sydney Technical College, with its six branch schools at Petersham, Newcastle, West Maitland, Goulburn, Bathurst, Broken Hill, and of the suburban and country classes is increasing by leaps and bounds. There were 295 classes with 6,688 students for 1891, about half of these are examined.

They include foundry, pattern shop, smith's shop, boiler shop, fitting and turning shop. The last is 75 feet by 45 feet, and can accommodate about 140 students working simultaneously. The classes connected with the technical college are arranged under twelve departments, viz., agriculture, architecture, art, chemistry, commerce, domestic science, geology and mineralogy, mathematics, mechanical engineering, pharmacy, physics, and sanitary engineering, and arrangements for the addition of new departments — electrical engineering, civil engineering, wool, and printing—during 1892 were made. Thirty-one candidates from the college passed the technological examinations of the City and Guilds of London Institute, and its art students did well in the South Kensington examination. The Technological Museum is a valuable adjunct, and branch museums have been established at four other centres. The expenditure on technical education was £37,601 in 1891, of this £3,721 was received in fees. The cost of buildings is separately provided for.

An agricultural department was not established until February, 1890, though previously there had been classes in the principles of agriculture under the Technical Education Department. The Hawkesbury Agricultural College and Experimental Farm, Richmond, was started in March, 1891. Students, who must be between 17 and 25 years of age, pay £25 per annum for maintenance and education, and there are six bursaries of this amount. The course extends over two years, and at the end a diploma is granted. Sites for farm schools for boys from 14 to 17 have been set apart, and also for four experimental farms.

Sydney University has a faculty of science and a department of engineering, and grants a degree in engineering, either for civil and mechanical engineering or for mining engineering.

Victoria.—"Technical instruction is not formally allied in any way to the State School programme." A large number of teachers have been trained in the kindergarten system, and paid teachers (either visiting or qualified staff teachers) give instruction in drawing to the fourth and higher classes.

The schools of mines and technical schools (schools of design, working men's colleges, etc.)—all now brought under the Education Department of the colony—have been liberally supported by the Government, which has given grants in the lump in aid of maintenance or for buildings. Thus, in 1890–91, £38,000 was expended in aid of nineteen institutions in all—half for maintenance, half for buildings. But there has not been sufficient regulation of the aid according to the merit of work done.

Systematic science and art classes are to be found in the Working Men's College, Melbourne, and the Gordon Technical College, Geelong, and in several similar institutions; but, apart from these, separate schools of art and design are established at no less than eleven centres, whose students submit themselves to the local South Kensington examinations.

The Victorian Schools of Mines have all along taken the lead and hold the first rank for completeness. They provide theoretical and practical instruction, not only in all subjects connected with mining pursuits, but also in the arts and sciences generally. Those at Ballarat and Sandhurst were established so far back as 1870 and 1873. At Ballarat, in connection with the Assay and Metallurgical Department, the mining laboratory is equipped with machinery and appliances for the reduction of quartz, and practical treatment of gold ore, and auriferous mine products; also a model mine is in the school grounds, with pumping and winding gear attached. At Sandhurst, besides the chemical and metallurgical laboratories, there are workshops for practical instruction in the mechanical arts and trades—*e.g.*, wood carving, engineering, smith and iron work, brass casting and metal work generally. The annual Government grants to the Ballarat and Sandhurst schools are £2,000 and £3,000 respectively. The Industrial and Technological Museum at Melbourne, opened in 1870, contains a most complete mineral collection, and class lectures are given there on chemistry and mineralogy. The colony possesses two agricultural colleges and experimental farms—Dookie and Longerenong—opened in 1886 and 1889, with accommodation for forty and thirty students respectively. They have been endowed by a grant of 150,000 acres of land, and involve a net annual expenditure of between £5,000 and £6,000. A payment of £25 per annum is required for each pupil.

Melbourne University, to which is affiliated the Ballarat School of Mines, grants degrees in civil engineering. The course of study for the Bachelor's degree is one of four years, and may be taken as representing the courses prescribed in the Universities of Sydney and New Zealand. The first two years are occupied with mathematics, natural philosophy, and chemistry. For the third year the subjects are—advanced surveying, mechanical drawing and descriptive geometry, applied mechanics, civil engineering (Part I.), drawing and quantity surveying. For the fourth year the subjects are:—Group I., Mechanical engineering, civil engineering (Part II.). Group II., Hydraulic engineering; architecture, practical, historical, and æsthetic; mining and metallurgy.

South Australia.—Practical work in gardening and tree-planting is carried out in connection with the schools, and pupils are prepared to compete for scholarships for the Roseworthy Agricultural College. This has been established since 1888, with a two years' course in practical and scientific farming, and a considerable amount of experimental work is done there.

The School of Mines and Industries (started in March, 1889), to which is attached the Technological Museum, provides for a three years' course, and its cost is met out of an annual maintenance grant (£3,000) and fees (about £1,000). The subjects taken by the classes include machine construction, pattern-making and shop drawing, and assaying and metallurgy. The School of Design, under the director for technical art, with branch schools at Port Adelaide and Gawler, confines itself to the artistic side of technical education. Students from the art schools, as well as from a number of secondary schools, present themselves for the South Kensington Science and Art

Examination, and for the local examinations conducted on similar lines.

At the Adelaide University, which has a science faculty, engineering is encouraged by an Angas scholarship (£200 for three years), and exhibitions (one each year of £60).

Queensland.—Mechanics, domestic economy, and needlework are taught in the State schools, but direct technical education is not yet provided for by the law, and the state of the public purse forbids the expense.

A vote of £5,000 was in 1891 passed for the purposes of an agricultural college, but the finances of the colony do not admit its immediate inauguration. The Curator of the Botanic Gardens carries on, with much success, horticultural classes for the more promising pupils attending the State schools. On Arbor Day (May 1) there were planted in the school grounds of the colony 4,968 trees, 365 shrubs and vines, and 27 flower beds were laid out. Two travelling dairies and a peripatetic mineralogical lecturer are supported by the Government. The visitors to the Queensland Museum within the year numbered a fifth of the population of the colony.

Tasmania has been hitherto in some respects backward, and drawing has been taught in very few schools. Some good work has been done by the Hobart and Launceston Technical Education Committees, and the Government are now making better provision, and have included in the estimates for 1893 a vote of £3,000 for a separate technical education branch of the Education Department, out of which small grants will be made to country technical schools, as well as to those at Hobart and Launceston, and for technical teaching in State schools.

In *New Zealand* the State schools are under the Education Boards of the several districts, who receive capitation grants from the Colonial Government. Practically all the scholars are instructed in drawing, but no manual work has been introduced, excepting needlework. In the case of two or three of the secondary schools, there is a workshop or a carpentry class. The technical school at Wellington and the school of art, Otago (Dunedin), are two flourishing institutions presenting a number of pupils for South Kensington certificates.

The principal schools of mines are at Thames, Reefton, and Dunedin—the last being attached to the University of Dunedin; but there are also several minor schools elsewhere. At the Thames school the syllabus for 1891–2 included lectures and instruction in practical assaying and metallurgy, chemistry, practical and theoretical, mineralogy and blowpipe, geology and geological surveying, mining, land- and mine-surveying, mechanical drawing. To the New Zealand University (incorporated in 1874) are affiliated the University College, Auckland, the Canterbury College, Christchurch, the University of Otago, Dunedin. The university issues certificates in engineering after a four-years' course, and has established a complete curriculum in engineering and technical science. The Canterbury College possesses a school of engineering and technical science, a museum, a school of art, and a school of agriculture at Lincoln. The Dunedin University in its completely equipped mining school, with a full staff of lecturers and professors, meets the requirements of all classes of students.

CAPE COLONY.

The educational problem in Cape Colony presents special difficulties, owing to the large coloured population and to the necessity for educating white and black children in separate schools. From the report of a Commission issued this year (1892), which deals with technical education in connection with the general question of education, it is apparent that its foundations have yet to be laid. In the primary schools, drawing has not been sufficiently attended to—it was taken by only 6,156 scholars in 1890, whilst 36,000 took music, and 18,000 (girls) sewing. In the majority of schools, elementary science is either ignored or taught perfunctorily. The Government grants £50 to certain schools in aid of what is called a "trade class." Where advantage is taken of the grant, this represents, for the boys, a carpenter's shop; for the girls, a dressmaking class.

Industries in the colony are in their infancy, and the proportion of lads who learn trades is small. In Basutoland native children have been taught building, shoe-making, tailoring, and turning, as well as farming and gardening as part of their education; and following this line, the Commission reports in favour of village technical schools suited to an agricultural and pastoral community. One of the larger secondary schools (Graaf Reinet) has just sent to England for a technical instructor.

There are two Government agricultural schools. The School of Agriculture and Viticulture at Stellenbosch with a two years' course of study, and an experimental field and dairy. Full time students in 1890 were thirteen.

The School of Agriculture at Somerset East had nineteen students in 1890, but these do not devote their time so exclusively to agriculture. There is an experimental garden, and a school dairy has recently been added. Instruction in bee-keeping is given both here and at Stellenbosch. Three bursaries of £20 each are offered by the Government.

Since 1887 the chemistry of metallurgy and assaying has been taught practically at the laboratory of the South African College, Capetown. In 1890 there were twenty-one students and an equal number were taking laboratory chemistry at the Diocesan College, Rondebosch. The Cape University grants a certificate of proficiency in the theory of land-surveying and an arts degree in mathematics and natural science. A school of mines for the colony has been proposed for some time, and Mr. Cecil Rhodes, the Premier, held out hopes, but the Commission in 1892 reported against the establishment of a school of science with special adaptations to sciences connected with mining industries, as a premature step.

THE CROWN COLONIES.

In Ceylon a technical school is just being started at Colombo under an instructor sent out from England. Hitherto some instruction of the kind has been provided by the chemical laboratories of the higher schools, the railway workshops, Government factory, etc., and these will continue to be utilised. A school of agriculture has been established for some time at Colombo, from which agricultural instructors go out into the country districts. The number of students for 1891 was twenty-six, besides those in branch schools. There is also a good museum at Colombo. At Moratuwa the colleges endowed by Mr. C. H. de Soysa, a munificent native gentleman, have done good work in promoting village industries, that of carpentry in particular. It should be added that a Gilchrist scholarship in engineering is awarded once in three years to a native of Ceylon on the results of the Cambridge Senior Local Examination.

In Mauritius deserving scholars are admitted as apprentices at the railway workshops and at the Botanical Gardens (twenty-three and eight respectively for 1891), and there are four needlework apprenticeships for girls. A scheme for technical education recently proposed was, that a school should be started in which certain artisans should be paid to exercise their trades to train the eyes and hands of pupils who, having passed the fourth standard, are unable to study for the higher standards through poverty or other causes.

In the West Indies little has hitherto been done, and the depression in the sugar industry has not permitted the consideration of any costly new departure, but there are signs of awakening interest. In Barbados a committee on technical education has reported in favour of establishing a school for 100 boys, between fourteen and fifteen years of age on admission, to be under apprenticeship for five years, and to be boarded and lodged at the public expense. They would be admitted by competitive examination, and choose a trade, and stick to it for the five years; the twenty first boys to be taught carpentry and masonry.

The Government of the Leeward Islands is taking up the question of agricultural instruction, and has secured the necessary powers to give industrial or technical training in any public elementary school. In British Guiana the Government encourages certain industrial schools by grants of 200 dollars, and there are some agricultural schools.

In Malta it has just been arranged to establish a school for technical instruction in connection with the railway. The apprentices are to be employed at first upon repairs of engines and carriages. Their education is to be continued, and special attention will be given to their instruction in drawing.

On the West Coast of Africa (Sierra Leone, Gold Coast Colony, Lagos) considerable attention is given in the elementary schools to domestic economy and sewing. In Lagos 64 per cent. of the girls on the register are taught sewing. At the Gold Coast the rudiments of agriculture are imparted in almost all the schools, and a beginning has been made in handicraft work (carpentry) and in practical cookery. Educated native opinion is fully alive to the need of something more than a merely literary education.

PLUMBING.—VI.

By a Practical Plumber.

(*Continued from p. 268.*)

PIPE FIXING, ETC.

Pipe Fixing, Astragals and Tacks.—The pipes, the making, bending, and jointing of which we have been studying, require to be fixed sometimes to wood, sometimes to stone or brick, both inside and outside of buildings, and various methods have to be adopted according to the requirements of the situation. One of the most usual methods is by means of "tacks" soldered to the back of the pipe in various ways.

Figs. 72 and 73 represent what are known as single and double tacks. Figs. 74 and 75 are secret tacks, and Figs. 76 and 77 fancy or ornamental tacks. Single tacks are fixed as shown, one on each side alternately, commencing a few inches from the top: 4 should be fixed to each 10-foot or 12-foot length of pipe; double tacks are fixed at top and bottom. Wall hooks are then driven in, as shown in Figs. 72 and 73, and the half-flap B is folded over the wall hooks, and lightly dressed close: some leave an extra flap, as shown at F (Fig.

73), and after the flap B has been closed down, this piece is bent down over it, thus helping to keep it

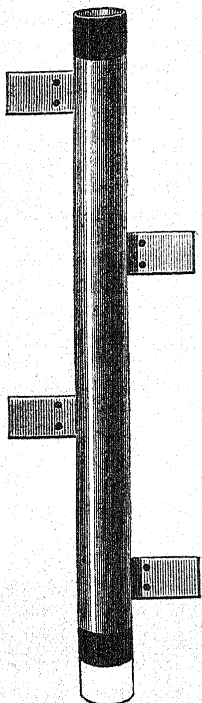


Fig. 72.

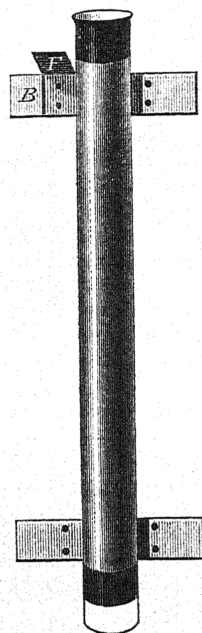


Fig. 73.

close, as well as preventing the rain and snow from rusting off the heads of the wall hooks or nails; this is a very good plan. Secret tacks are used when the pipe is fixed in such a position that ears or tacks of the ordinary kind are not admissible. Many people object to the tacks being seen on each side of the pipe. Secret tacks may be made by cutting away the front of the pipe, as shown in Fig. 74, so as to leave a kind of lug or ear at the back; this is fastened to the wall with wall hooks, and then when the next length is put in the hooks are not seen. When pipes have to be fixed to wood, for instance, a boarded chase in a

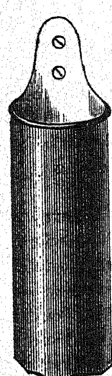


Fig. 74.

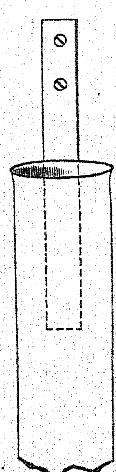


Fig. 75.

wall, the same result is obtained in a different way (Fig. 75). In this case a stout strip of lead or lead-pipe flattened is soldered to the back of the pipe, and brought up several inches above the top of the pipe, and then screws used instead of wall hooks.

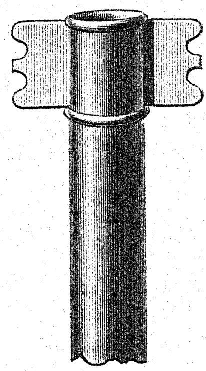


Fig. 76.

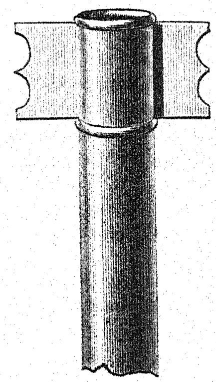


Fig. 77.

I do not consider this so strong a mode of fixing as the side tacks, but of course necessity compels it sometimes. Many plumbers use nails for fixing

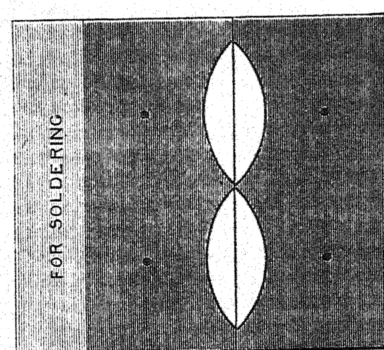


Fig. 78.

pipe, but hooks are better, as being wider they afford much more support to the pipe.

Ornamental tacks are made by setting out some geometrical pattern on the centre line of each tack, as shown in Fig. 78. When cut out and doubled over, it will be as Fig. 77. This is a very simple design, but they can be cut to any pattern according to the taste of the workman.

Sizes of Tacks.—As a general rule the length of the tack or ear (that is, measuring in the same direction as the pipe runs) should be twice the breadth of the pipe, and its width $1\frac{1}{2}$ times the diameter, exclusive of the piece that is soldered at the back, which in the case of a 4-inch pipe would be about $1\frac{1}{2}$ inch. Thus a pair of tacks for 4-inch

pipe would be cut $7\frac{1}{2} \times 8$ inches; some might cut them even larger than this, but too wide tacks do not look well, especially when plain.

Fixing the Tacks to Pipes.—This is done by wiped soldering as follows. Take a length of soil-pipe, shave and soil it if for double tacks as Fig. 79,

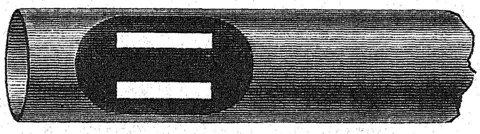
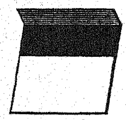


Fig. 79.



shave the tacks 1 inch wide, and slightly bend the shaved part back so that a V-shaped body of metal may join them to the pipe, as shown in section (Fig. 80). Rest the pipe on the blocks as in soldering the seams, and block up the tacks to them; fix so that they will not shift in wiping; then, ladle in hand, splash on to get up the heat, and when the solder is nice and soft, wipe quickly, and cut off surplus metal at the ends with a chipping knife (Fig. 81). It is important that these tacks should be soldered securely, so be sure that the parts are well "tinned" before commencing to wipe.

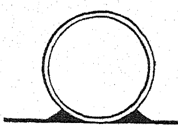


Fig. 80.

Another kind of tack is known as the band

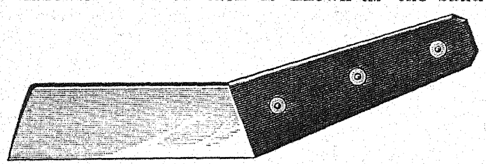


Fig. 81.

tack: this, as its name implies, is a band of lead bent round the pipe with a slot cut out of it in front which is wiped to the pipe—useful for places where it is not practicable to get pipes through with ears soldered on, also when additional tacks are required to be fixed: it is shown at Fig. 82, and requires no further explanation.

Tacks to Small Pipes.—In fixing small pipes, such as service pipes, supply pipes to w.c.'s from cisterns, wastes, etc., many plumbers use wall hooks or pipe hooks, driving them so tightly into the wall as to hold the pipe firmly. This is wrong. Two reasons will show that it is so. First, there is a risk of flattening the pipes to a certain extent, either by driving the hook in too far, or by a miss blow from the hammer, and there is also a risk of damaging the pipe with the sharp edges of the hooks; so that while iron pipe may safely be secured in this way, it is certainly best to fix small lead pipes with tacks the same as just described.

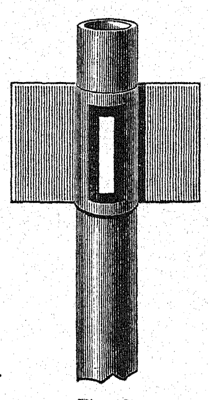
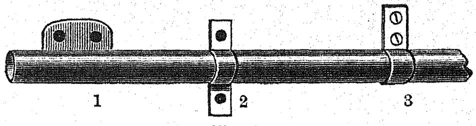


Fig. 82.

Fig. 83 shows a horizontal line of pipe with three methods of supporting it: 1 is a tack soldered at the back, 2 is a band tack, 3 a sling tack, any one of which is preferable to pipe or wall hooks.

An error of judgment the writer has frequently seen in pipe fixing is when a pipe, passing through a wall, is continued downwards, perhaps 20 or 30 feet or more, and the workman, not knowing or not properly appreciating the



1 2 3

Fig. 83.

effect of the weight of such a length of pipe, he consequently merely drives in two or three pipe hooks down the vertical length, which may or may not grip it firmly: if they do not, and if by any means (such as vibration in the pipes) they become loose, the weight of the pipe will flatten it at the bend, diminishing its effective service to perhaps half what it should be; with soldered tacks this could not happen.

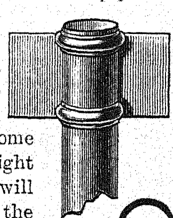


Fig. 84.

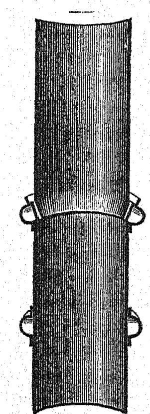


Fig. 85.

Astragal Joints.—Astragals or bands are usually placed at the top of each length of pipe for a sort of relief or ornament, as well as for strengthening the pipe. Fig. 84 shows a pipe with astragals; Fig. 85 is a section of the astragal. They are bent round the pipe and soldered to it; sometimes they are formed from pieces of $\frac{1}{2}$ or $\frac{3}{4}$-inch lead pipe, but the proper cast strips are the best. An astragal joint is made by cleaning the inside

of the lower pipe and the top of the astragal and the lower part of the entering pipe and soldering it to both the pipe and the astragal, as shown

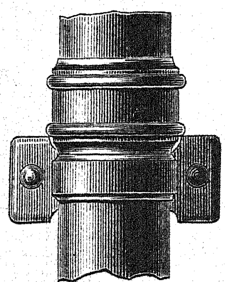


Fig. 86.

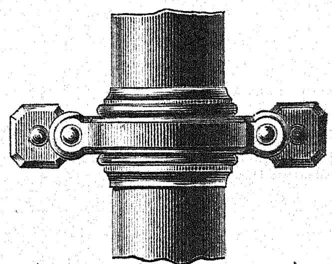


Fig. 87.

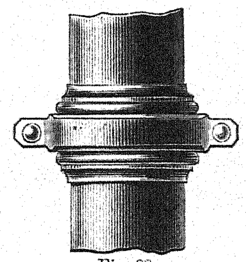


Fig. 88.

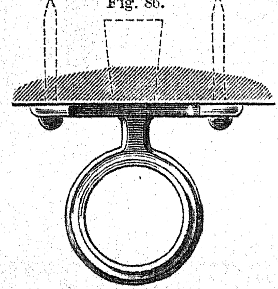


Fig. 89.

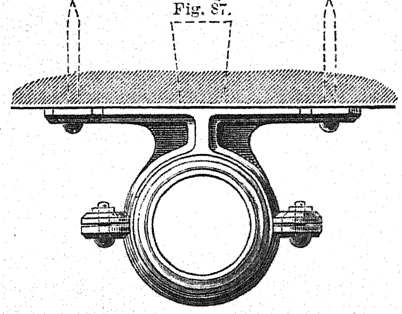


Fig. 90.

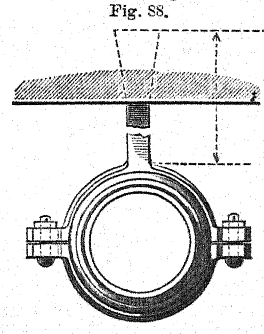


Fig. 91.

in section (Fig. 85), either by fine soldering or wiping. Lead pipes should never be fixed where the sun will shine full on them if it can be avoided, as the heat will expand and warp them; where this is unavoidable, the joints must be slip joints, that is, each length laps in the other about 3 inches; of course it will not do to fix soil pipe in this style, unless on a wall where there are no windows. The plumber has frequently to make use of iron pipes both for soil and also for rain water: these are made with a socket and ears and are fixed with proper stack pipe nails. The latest improved method of fixing this kind of pipe is to keep it away from the wall an inch or two. The backs of the pipe can then be seen, and they can easily be got at to be painted, which must be done at not long intervals if the pipe is to last any length of time. Even then cast-iron pipes are not very long-lived comparatively speaking, for there is a constant corrosion and eating away from the inside unless galvanised, and then of course they last somewhat longer; but I cannot help saying that, however suitable they may be on account of their moderate price, as compared with lead for such work as small houses and villas, it is a great mistake to use them on institutions, mansions, etc., as I have seen them used. Good stout lead pipe will, bar accidents, last hundreds of years, whilst I think most in the trade will agree that if we allow fifty years for the life (if we may so term it) of a cast-iron pipe, it will be a fair estimate. Some pipe would not last twenty years. However, to return to the fixing, Figs. 86, 87, 88 are illustrations of patent bands and ears for the purpose of projecting pipes from walls, and Figs 89, 90, 91 show them in section. Fig. 86 is a plain band through which the pipe is slipped and is supported by the socket as shown in section (Fig. 89). In Figs. 87, 88 it will be seen that the bands are in two halves. Fig. 91 has no ears, but is built into the brickwork or masonry and can project any required distance. These patent bands can be had with or without bats for building into the brickwork, and there are other designs, but these will suffice to illustrate the mode of fixing them. Messrs. Stevens Bros. make them, and they certainly mark an advance in the fixing of iron pipe.

For setting the ordinary pipe with ears away from the wall, a round and slightly tapering block of cast-iron is placed between each ear and the wall, and nails driven through into the wall. When cast-iron pipes are used for conducting soil, all joints must be properly made: it is not sufficient to just daub a little red lead cement round the top of the socket, which, I am sorry to say, is all that many workmen do. (*See* "Lead Caulked Joints," p. 137.)

STEEL AND IRON.—VI.

By William Henry Greenwood,
F.C.S., M.Inst.C.E., M.I.M.E., Assoc. Royal School of Mines.

[*Continued from p.* 264.]

CRUCIBLES.

Steel-melting Crucibles or pots are of the form and proportions shown below (Fig. 3). They measure from 16 to 19 inches in height, are about 9 inches in diameter at the widest part, and from 6 to 8 inches in diameter at the mouth; they are capable of holding charges of about 75 pounds of bar-iron or blister-steel, previously sheared into small pieces. These crucibles, when in the furnace, stand upon a conical foot or stand (*d*) for raising the pot above the furnace bars, and also to enable the hole in the bottom of hand-made crucibles to be stopped with sand before metal is charged into them. After the charge has been introduced into the crucible the mouth is covered by a loose lid, *c*; this and the stand *d* being made also of fire-clay, but of a somewhat cheaper variety than the pots themselves. It is the practice on the Continent, where machine-made pots with solid bottoms are employed, to make the lid *c* with a small hole through its centre, which is closed by a loose central stopper.

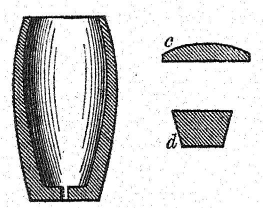


Fig. 3.—Steel-melting Crucible, Cover, and Stand.

Mixtures of clays are preferred for making crucibles: thus, for those used in the melting of steel, one mixture consists of 5 parts of Stourbridge-clay, 5 of china-clay, 1 of old ground pots freed from adhering slag, and $1\frac{1}{2}$ parts coke dust. These ingredients are ground fine, so as to procure uniformity in the size of the particles, and are mixed on the floor, where water is thrown over them, and the mass is systematically kneaded by workmen treading it barefooted for several hours, the clay being turned over with the spade at intervals; the mass is then cut up, and weighed into portions called *balls*, each sufficient for one pot (crucible); each *ball* is worked by hand on the table or bench before being thrown into the well-oiled flask, *b* (Fig. 4). The plug, *a*, is then forced into the mass of clay by alternately lifting it up and pressing it down again, the concluding pressure being obtained by striking the plug two or three smart blows with a large wooden mallet. In this manner the clay rises all around the plug, and fills up accurately the space between the inner surface of the mould or flask and the body of the plug. Finally, by a dexterous twisting movement of the plug, which is at the same time lifted upwards by a pin passing through its eye-stud, *d*, it is withdrawn, leaving the clay in the form of the crucible inside the flask. After extracting from the flask *b*, a mould of tin-plate of the form of the frustrum of a cone is placed upon the mouth of the crucible, pressing it inwards to the form shown in Fig. 3. The crucible is then removed by carefully lifting it with the aid of a pair of sheet-iron plates, fitting around the sides of the crucible, and it is placed upon the shelves in the pot-house, where the crucibles are allowed to dry slowly for from twenty-four to forty-eight hours, before they are removed to the shelves around the steel-house, where they remain about a fortnight, so as to be thoroughly dried. Before inserting them into the melting furnace, they are annealed for from fifteen to eighteen hours in a separate oven, whence they are removed while still hot, for insertion into the melting hole or furnace.

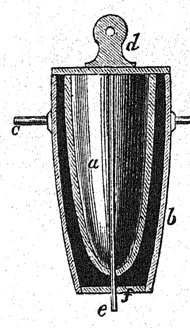


Fig. 4.—Flask and Plug for Crucible-making.

In *machine-made crucibles* the operations are the same as those above described, except that the plug for forming the inside of the crucible is driven into the ball of clay thrown into the bottom of the mould or flask, and withdrawn by a suitable mechanical arrangement instead of by hand labour; and instead of drying upon shelves, the green crucibles are removed from the pot-house and arranged upon suitable shelves in a series of chambers, where they remain about a fortnight, heated air being in the meantime propelled by a fan through the chambers, whereby the temperature is gradually raised to between 75° C. and 85° C. (167° F. to 185° F.).

THE BLAST-FURNACE.

The production of pig-iron from the various ores of iron comprises: 1st, *The preparation of the iron ores;* 2nd, *Smelting in the blast-furnace.* Of these stages, the first-named has already been considered; while for the smelting or reduction of the iron ores, and recarburisation of the reduced metal to pig-iron, with the separation of this latter by fusion from the earthy constituents of the ore, it is necessary that the furnace be of considerable height, and that a blast of atmospheric air be delivered into the same, at a pressure sufficient to force it freely through the superincumbent mass of fuel and ore in the furnace. Further, the twyers through which the blast is delivered into the furnace must be laid horizontally,

for if directed downwards into the bath of molten metal, then malleable iron would result, as occurs in the Bloomery furnaces, instead of the pig-iron required to be produced in the blast-furnace. The high blast-furnace appears at present to be indispensable for the production of pig-iron, although, as will subsequently be shown, wrought or malleable iron can be produced directly from iron ores without the intervention of the blast-furnace.

The blast-furnace and its accessories occupy a very small area, considering the very large amount of materials treated. Thus, the larger Cleveland furnaces — one of which will treat annually about 120,000 tons of materials, consisting of ores, fluxes, and fuel, and producing therefrom about 25,000 tons of pig-iron, or 60,000 tons of pig-iron and slag, together — will, with the necessary stoves, engines, kilns, hoists, room for storage, and other accessories, occupy only about half an acre of ground, and cost broadly about £25,000 for its erection. The labour also connected with the production of pig-iron is small, being for the working of two furnaces each producing 450 tons of pig-iron per week, three keepers, two slagmen, five fillers, and two top-chargers, or a total of only twelve men find employment at the furnaces themselves. Such furnaces in this country will make about 350,000 tons of pig-iron before requiring to be relined.

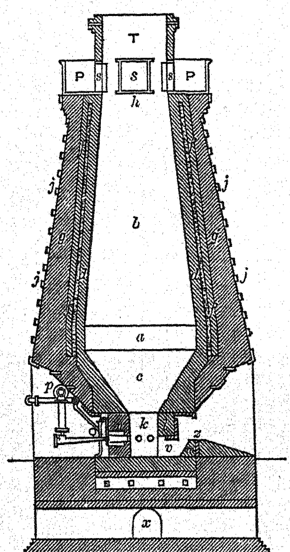


Fig. 5.—Sectional Elevation of a Staffordshire Open-topped Blast-furnace.

The modern blast-furnace may be considered to be a closed chamber or hearth, whose side walls are carried upwards so as to form a body or shaft, which is generally circular in all horizontal sections, except in the Rachette furnace, which is rectangular in horizontal section. But the *older form of blast-furnace* illustrated in Fig. 5 is open at the top, and has an internal shape like that of two truncated cones, *b* and *c*, of which the bases are joined by a narrow cylindrical belt, *a*, known as the "*belly*" of the furnace. The upper cone *b* forms the "*stack*" or *body* of the furnace, and it is larger and deeper than the lower or "*boshes*," *c*, and while the boshes are built either of fire-bricks or of slabs of a refractory sandstone, the stack has an internal lining, *d*, of from 15 to 18 inches in thickness, of fire-bricks set in fire-clay, and outside of which is a casing of refractory sand or broken scoriæ, supported by a concentric wall of brickwork, *f*; while outside of all is the massive brick or masonry casing, *g*, which is all well and strongly tied together by stout bands or hoops of iron, *j*. The masonry is further prevented from splitting during drying or heating-up, by building numerous channels throughout the outer casing of masonry by which the escape of water and drying of the furnace are much facilitated. The upper cylindrical part *h* of the furnace is known as the *throat*; and in open-topped furnaces—that is, such as allow the gases and flame to escape directly from the throat into the atmosphere—the throat is surmounted by a "*tunnel-head*," T, of from 8 to 12 feet in height and from 8 to 9 feet in diameter, which thus serves to carry the flame clear of the charging-holes *s*, which in such furnaces are built in the sides of the tunnel-head. In close-topped furnaces the tunnel-head is unnecessary.

Around the throat of the furnace is carried a platform, P, giving a free passage to the barrows and waggons conveying the ore, fuel, and fluxes to the charging apparatus. The boshes, *c*, slope gradually to the *hearth*, *k*. In the heavy foundation of fire-stone or fire-brick, arched galleries, X, are left for taking away moisture and keeping the foundation perfectly dry; while the bottom of the hearth usually takes the form of a flat inverted arch, the concavity of which is upwards so as to prevent the bottom from being raised by the accidental escape of metal beneath it. In front of the hearth *k* is an opening in the masonry, the crown of which, *l*, known as the "*tymp*," is made either of a block of refractory stone, or of a hollow cast-iron bearer or box built in the masonry, and through which a current of water circulates to keep it cool, and to protect it from the heat, and from the corrosive action of the slags. A little below and in front of the tymp is a prismatic stone, *m*, called the "*dam-stone*," supported on its outer side by a cast-iron plate known as the "*dam-plate*," *z*. The portion of the hearth or space behind the dam-plate, which is arched over by the tymp-arch, is known as the "*fore-hearth*," *v*. A circular notch cut in the upper edge of the dam-plate constitutes the "*cinder-notch*," and through this the slags run out from the furnace and flow to the "*cinder-tubs*," or to the "*roughing-hole*" as used in Staffordshire; whilst a vertical slot through the dam and dam-plate,

extending to within about 18 inches of the bottom of the hearth, forms the "*tap-hole*," *t* (Fig. 6), which is closed by a stopping of sand or clay tightly rammed into it, and which stopping is penetrated by a pointed bar, as required, for tapping out the metal from the furnace. The twyer-holes, *n*, are four to six or seven in number, and are arranged around the circumference of the hearth and at some distance from the bottom. At *p* is the "*blast-main*," from which descends a pipe to each of the "*water-twyers*," *q*. The boshes and hearth of the furnace are subjected continuously to the most intense heat of the furnace, as also to the scouring action of the slags, and the period of uninterrupted work of the furnace depends largely upon the duration of the boshes, the materials for which (fire-bricks, or fire-clay lumps) cannot be too carefully selected and built together.

The massive structures we have just described, with their open tops from which flame and gases escape uselessly into the atmosphere, have been generally discarded, except in some of the South Staffordshire and Scotch furnaces, in districts where coal is cheap and the loss of heat and waste of fuel in the escaping gases have been considered of little importance, and the modern practice, adopted in Cumberland, Wales, etc., for the smelting of hæmatite iron ores, and in Cleveland, etc., for smelting clay-ironstones, and extending into Scotland, is to build furnaces upon the *cupola type*, with closed throats and arrangements for collecting the waste gases and burning them either under steam boilers, or in the stoves for heating the hot-blast. Such furnaces have walls much thinner than those last described, and to secure still thinner walls, as also to better support the hearth and boshes, these last-named parts have occasionally been constructed of hollow cast-iron boxes, through which water is made to circulate, or in which coils of water-pipes have been contained, such "water-jackets," as they are termed, being lined with only a few inches of brickwork. In these furnaces also the internal form consists of more or less continuous curved lines running from the throat to the hearth (Fig. 6), without the conical forms and sharp alteration in the slopes at the hearth, boshes, and stack of the furnace as shown in Fig. 5. The several parts of the furnace continue, however, to be distinguished by the same names, and in Figs. 6 and 8 the same letters of reference and names apply as in Fig. 5.

In the cupola blast-furnace (Fig. 6) the body or stack is formed of a wrought-iron casing of $\frac{3}{8}$-inch or $\frac{1}{2}$-inch plates riveted together, and within which is built the outer walls *f* of ordinary brickwork, inside of which is the fire-brick lining *d*, about 18 inches in thickness, built up of 5-inch fire-brick lumps all carefully dressed, faced, fitted, and laid to the exact radius of the furnace in its several parts; while between this inner fire-brick lining and the outer casing of ordinary brickwork a small space is sometimes filled with sand or furnace scoriæ. The stack or body of such a furnace is carried upon a cast-iron ring, R, resting usually upon iron columns; and the lower conical part is also built in a conical wrought-iron casing supported upon cast-iron stanchions and the brickwork of the hearth; or, instead of the wrought-iron casing, the water-jacket, already mentioned, is substituted.

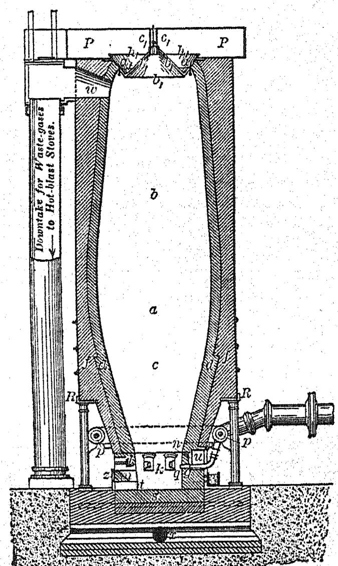


Fig. 6. — Vertical Section of the Cupola Blast-furnace.

The conical portion extends from above the tymp-arch, *l*, to the top of the columns carrying the stack. The hearth *s* is independent of the masonry of the stack, and is built in after the stack is completed.

The foundation of the furnace hearth is a massive formation of brickwork resting upon clay or other solid base, and is encircled by a stone curb, upon which the columns carrying the stack stand. The bottom, *s*, of the hearth of the furnace is formed either from large blocks of a refractory sandstone, or of two courses of fire-brick lumps set on edge and breaking joint, so as to make a thickness of about 4 feet 6 inches; and it is built in the form of an inverted arch of slight curvature, the concavity being upwards, since this form is the best adapted to prevent the hearth from being forced upwards by the accidental entrance of metal

beneath the brickwork during the working of the furnace. The hearth is lined in England with the best fire-bricks, but in Norway and Sweden it is lined with a mixture of powdered quartz, fire-brick, and fire-clay, well rammed in. On the under side of the tymp-arch there is fixed a cast-iron box, u, in which is a curved iron pipe through which a circulation of water is maintained, thereby rendering this part of the furnace better able to resist the corrosive action of the slags which are constantly flowing out from beneath it.

Cupola furnaces, such as those just described, when employed in the smelting of hæmatite ores, will measure upon the average 65 feet in total height from the hearth to the platform, with a diameter of 18 feet at the boshes and 7 feet at the hearth, while the throat or bell-opening is 9 feet in diameter, and the furnace has a capacity of about 15,000 cubic feet. The Cleveland furnaces of the same type, but working upon clay ironstones, have reached to over 100 feet in height, with a diameter of 25 to 30 feet at the boshes, and a capacity of from 30,000 to 40,000 cubic feet. These furnaces are without tunnel head, but are fitted with some arrangement for closing the throat more or less completely, and for drawing off the heated and combustible gases which ascend to the throat during the regular working of the furnace. For this purpose the *cup and cone* arrangement, shown in Figs. 6 and 7, by which the throat is entirely closed and the gases wholly collected, is generally adopted. It consists of a cast-iron cup or funnel-shaped casting, a_1, of which the diameter at the lower end is about one-half of that of the throat of the furnace into which it is built; and beneath the lower opening of this funnel-shaped casting a cast-iron cone, b_1, is suspended with its apex upwards by means of a chain, links, or other means, c_1, from a counterpoised lever, d_1, the balance-weight w (Fig. 7) being adjusted so as to slightly preponderate over the weight of the cone b_1, and thus to keep it constantly against the mouth of the cone a, thereby effectually closing the throat of the furnace. The gases then pass out from the side of the throat through the pipe w (Fig. 6). The cup and cone arrangement at the same time forms a kind of annular hopper, h_1, into which the supply of ore, fuel, and limestone is delivered and retained until it is let fall into the furnace by lowering the cone b_1, when owing to the form of the cone, the charge is spread with tolerable uniformity over the surface of the materials already in the furnace, so as to afford a good draught and a uniformly free passage for gases ascending from the hearth to the throat. The only time during which the throat is open to the atmosphere is the short interval during which the cone is depressed for dropping the charge into the furnace.

Various mechanical devices are in use for controlling the movement of the cone b_1, a frequent form being to attach a toothed segment to the opposite extremity of the lever d_1 to that at which the

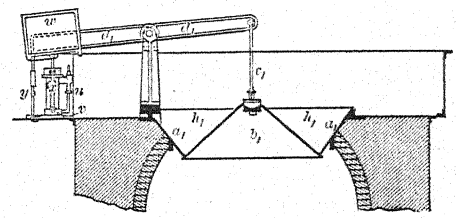


Fig. 7.—Cup and Cone Arrangement for Closing the Throat of the Blast-furnace.

cone is suspended, and into which segment is geared a toothed pinion worked by a hand-wheel. Another method, illustrated in Fig. 7, is a cataract arrangement, consisting of a cylinder, x, in which works a solid piston connected by a rod to the lever d; the cylinder is filled with water, whilst its two ends are connected together by a pipe, u, in which is a cock at v, so that the ascent or descent of the piston, and thus of the cone b_1, cannot be effected unless the cock v is open, for the water to flow from one end to the opposite end of the cylinder x. Therefore, when the cone b_1 is lowered, and the charge has fallen from the hopper h_1 into the furnace, there is then a small preponderance in the weight w, tending to raise the cone and close the furnace mouth, but this movement cannot take place until the cock v is opened to allow of the passage of the water from the under to the upper side of the piston in the cylinder x; hence all that is necessary is to open the cock v, and the mouth of the furnace is immediately closed.

COTTON SPINNING.—VI.

By Henry Riddell, M.E.

[*Continued from p. 273.*]

OPENING (*continued*).

Lap Device.—In most openers now being constructed a lap-forming arrangement is being used, except where the connection between the opener and first scutcher is made by an air-trunk. It is advisable to form a lap at the earliest operation possible, and to use the utmost precaution towards making the lap of the greatest regularity obtainable. As the sheet of cotton leaves the machine, it is caught by a pair of smooth calender rollers and delivered upon the top of a pair of fluted rollers,

upon which the roll of cotton lies, and is formed around a central bar. The roll or lap is, of course, driven by the frictional contact with the underlying fluted rollers. The lap-roller, or central bar, should be bored for the patent lap-rods—rods having a large flange upon one end as a head—so that when the lap-roller is withdrawn to begin another lap, the rod is left behind, held by the flanged head, which

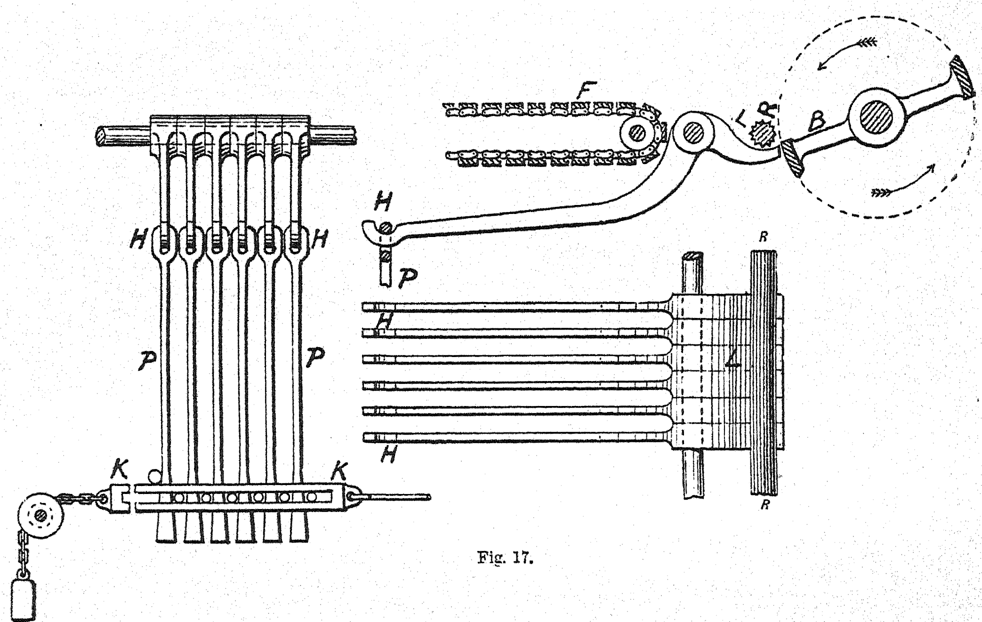


Fig. 17.

is too large to pass through the hole left by the lap-roller. Without this, or some similar contrivance, the central hole in the lap closes up soon, and causes waste by stabbing in wrong places when inserting an axle for use in either the breaker or finisher scutcher. An attachment is usually provided for stopping the machine when laps of a certain diameter have been formed.

Pedals.—The pedal arrangement, due to the late Mr. E. Lord, is an exceedingly valuable invention, designed to govern the feed automatically, so as to render the passage of the cotton through the machine, and therefore the lap, very regular. To it is due a great part of the success in the modern economical treatment of cotton. Referring to Fig. 17, it will be seen that the lattice feed F delivers upon the surface L, composed of the flat or slightly hollowed ends of a set of levers strung closely upon a shaft. The other ends of these levers are formed into the hooks H, upon which are hung a series of pendants, P, having their lower ends for some inches widened out wedge-shape as shown. The wedge-shaped ends pass through a frame, K, formed from two bars held a suitable distance apart by means of studs, and bear upon a series of small rollers so placed between the bars as to act each upon one side of one pendant only. If now a larger lump of cotton than usual reach the feed-roll, R, one or more of the levers will be depressed, and the corresponding pendant will rise, and the wedge-shaped end will tend to separate the pair of bowls with which it is in contact. All these bowls, except the outside one on each side of the machine, are free to travel, their axles running in grooves in the two bars forming the frame before mentioned. If now one outside bowl be fixed to the framework of the machine, and that at the opposite side to the bar-frame, it is plain that as the pendants rise this bar-frame, with all pendants nearer the movable end, will be forced towards one side of the machine, and, as they fall, it may be drawn back again by a counter-balance

This action is made to shift the belt upon a pair of cones, driving the feed slower as the lever noses are depressed by cotton lumps, and faster as the cotton lessens in thickness. It is clear that the effect of this action depends upon the number of levers depressed and the amount of their depression. The use of two separate bowls between each pair of levers is due to the necessity of avoiding friction, which would be caused if two pendants, bearing upon one bowl between them, rose at

one time, tending to turn the bowl opposite ways, and thus rendering it useless as a preventer of friction. The levers often rest upon a knife-edge instead of being strung upon a shaft, their noses sometimes vary in shape for different cottons, and a pair of feed rollers often receive the cotton from the pedals before delivering to the beater B.

Dobson & Barlow's Opener.—To return to the figure (Fig. 15) representing this machine, the cotton, after passing through the pedal delivery, is thrown directly upon the rapidly revolving cylinder, which has already been mentioned as belonging to a modified willow type, and is placed beneath the lattice, as may be seen in the diagrammatic section (Fig. 16). This cylinder is partially cased in by iron plates, armed internally with strong conical teeth to aid in the shaking and cleaning of the cotton. The impurities thus dislodged are discharged through a series of grate-bars, graduated in spacing, which supply the part of a casing to the lower half of the cylinder. There are usually three sets of these grate-bars, each set having its own separate dust-box. After passing over these grids, the cotton travels across a second series of bars to the dust-cages D. These are cylinders having a surface of perforated metal or wire gauze, and open at both ends to an air-passage which is kept exhausted by means of a fan. The draught caused by this exhaustion sucks the cotton against the surface of the perforated cylinder, which is kept revolving, causing the cotton to bind into a kind of sheet, and making it possible to strip it off by means of the rollers shown at R. In addition to the duty of bringing the cotton to the surface of the cages, the air-current forms the motive power drawing the cleaned material over the grids after leaving the cylinder. The rollers which strip the cage deliver the cotton to the scutcher-beater S, which is usually three-winged, and thence it travels to another set of dust-cages, and is then stripped by a pair of pressure calender rolls, and given to the lap-forming attachment shown.

In this class of machine the management of the air is as important as in the use of air-trunks, and dampers are usually supplied by which the current can be regulated. The grids between the cylinder and the dust-cages are provided with means of adjustment, by which they can be set to any angle required. Another adjustment is provided, by which the angle and distance of the beater bars can be suited to the particular class of cotton being worked.

These openers are suited for American and Egyptian cotton; and machines of this class are constructed by different makers with various combinations. Howard & Bullough use a beater of the type represented by the Crighton opener, but placed horizontally, followed by a scutcher and lap device. Lord Brothers make a combination of the vertical Crighton and a scutcher, and the various machines are combined by other makers in all possible ways.

From an opener the cotton should be delivered in a good, open, elastic condition, and where a lap arrangement is used, of course an even thickness and width of the lap is required.

This even width is sometimes obtained by the dust-cage cylinder running between two smooth flanges, into which its ends are sunk, leaving all the width of the cylinder between these flanges perforated to receive the cotton. In other machines the directing of the air-current is relied upon for the purpose. Where a series of machines are used by transferring the lap of one machine to the feed of another, the same result is obtained by making each lap slightly narrower than its predecessor.

Scutching.—From the opener the lap is taken to the scutching, which may be carried out in one, two, or three operations, as best suits the cotton and the class of yarn to be spun. In most cases it is advisable to avoid working the cotton more than is necessary, as all such work tends to take away a portion of the strength and elasticity of the material and add to the waste.

The principle and construction of the scutching machinery has already been described in connection with the opener, and it is sufficient to say that, where not fed with a lap, the machine generally possesses the pedal feed, and has the beater, dust-cages, and lap attachment. The beating mechanism is very often repeated in the same machine, the cotton being twice operated upon. In feeding the first—or, as it is called, the breaker-scutcher—the plan is adopted of feeding two, three, or four laps together, matching their weights to produce a lap of the proper weight for succeeding processes. By this means the laps are made much more regular in thickness from the breaker, and also from the finishing scutcher, where the same method is employed, as the chances are that thin places in the different laps will not fall together in the doubling, and that any irregularity will be removed nearly in proportion to the number of laps compounded. Of course, a "draught" is introduced in this method of working, the finished lap being, at any rate, no weightier than either of those run together in its composition.

In former times the cotton was always in a loose condition from the opener, and weighed out upon a spaced feed lattice on the scutcher. At present, however, lap attachments are so common upon the first openers that this method is almost abandoned;

although, when properly carried out, it provides a lap unsurpassed for regularity.

The saving of expense is so great by using the lap from the opener, and the usual weighing was so carelessly done, that the spinner has found the balance of advantage in the use of the more modern method.

In America, however, the Bramwell feeder has been altered to suit the cotton manufacture, and, introduced by the firm of Harwood & Son, Boston, has attained some popularity. This machine was of American invention, and is largely in use among the Yorkshire woollen mills, and also in the tow departments of Irish flax mills, for card feeding—a duty which it performs automatically with a very high degree of regularity.

It is a question for consideration among those spinners who are not yet satisfied that laps are as perfectly made as they should be, whether a similar use of this feeder might not be an advance upon present practice. Fig. 18 represents a scutcher which may be used either as breaker or finisher, but there are no points connected with it which require detailed description.

So much of the regularity of the lap produced by these machines depends upon the management of the air current upon the dust-cages, that it may be here mentioned a second time. The most important function of these cages is the formation of a lap, and anything which tends to alter the force of the current upon any part of the cage surface also tends to alter the thickness of the cotton fleece there attracted. When a certain thickness of cotton, largely dependent upon the character of the air current, has been deposited upon any part of the surface, the air ceases to pass through there and the cotton floats towards another spot, hence any irregularity in the perforation, however caused, is accompanied by a corresponding irregularity in the fleece; also any derangement of the draught by leakages through joints in covers, etc., has a similar effect. Therefore it is certain that among the adjustments of the scutching machines none are more worthy of attention than that regulating the exhaust.

All the exhausts should be conducted through pipes of ample size and easy curves to a large flue leading to the outside of the building, and these flues require as regular cleaning as other appliances.

Production.—It will be understood that the production of any machine varies greatly according to the class of cotton, but the following may be taken as approximate.

The Crighton opener is capable of cleaning and opening satisfactorily, at beater speeds varying according to the cotton, 25,000 to 35,000 lb. per week. The bale-breaker can about supply this amount of pulled fibre, while if a porcupine feed is employed to the Crighton opener the production will scarcely be altered. The openers which combine two different principles vary considerably in their out-turn; that represented in Fig. 15 has a capacity of about 20,000 to 25,000 lb. per week when working upon American cotton.

Where the better classes of cotton are used the action of the machine is rather slower, owing to the necessity of dealing tenderly with the long fibre; a production of about 15,000 or 16,000 lb. per week might be taken as a good average. The scutching machines employed for either breaking or finishing may be reckoned on for something like the same amount.

These figures vary considerably according to the cotton, and also according to the views of the manager responsible.

Calculations.—Hank-Draught.—The calculations required in a cotton mill are mostly of a simple character, and examples will be found throughout these lessons wherever it is thought at all necessary. Instead of inserting a number of tables, which are not generally used, the principles of each calculation will be explained, and tables supplied only where by employing them a considerable amount of labour can be saved.

The first calculation which it is necessary to deal with has reference to the speeds of the machines; and as all such problems are solved in a similar way, it is better to explain the method at this stage, and follow any special applications which may require notice when dealing with the machines concerned. The following is the ordinary

Rule.—Multiply the speed of first motion shaft by the product together of the diameters of all the driving pulleys, and divide by the product of the diameters of all the driven; the quotient is the speed of last mover. Where wheels are employed, the number of teeth in each wheel is to be used instead of the diameter in the above rule.

With regard to wheels, what is called an idle wheel—that is, one which is itself both driver and driven—may be omitted from the work, as it only effects direction of motion and not speed. In any driving arrangement the number of driving wheels or pulleys must always be the same as that of the driven; so that if in working out speeds practically any difference in this way is noticed, an error in taking particulars must be looked for. In driving all machines the question of direction of motion requires consideration, and where there are many intermediate steps between first and last mover it is well to bear in mind that, where wheels are used,

an even number of drivers gives a motion the same in direction as the first mover, while an odd number reverses it. It is unnecessary here to give examples,

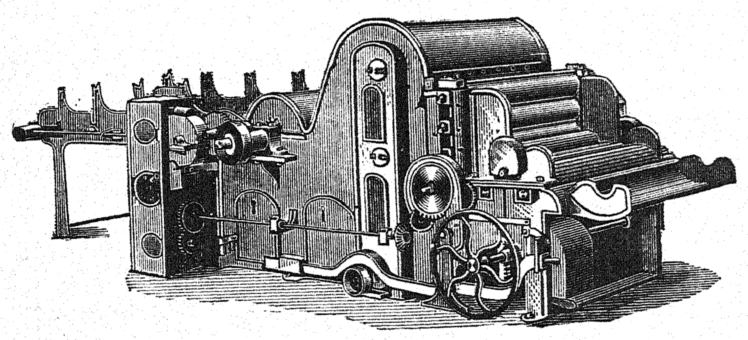


Fig. 18.

which will be found in connection with such machines as the card and the mule, where the steps in the driving are many.

One calculation which may now be given is required where the cotton is weighed out upon a spread-board, or lattice-creeper, divided into measured spaces for the feeding of an opener or scutcher.

Let it be supposed that the creeper is divided into spaces of 54 inches in length, and the lap is required to weigh 10 ounces to the yard, with a "draught" in the machine of 4.

The draught of a machine is found by dividing the surface speed of the delivery by that of the feed. This is not quite the same as the draught of the cotton, as it makes no allowance for waste. The draught of the cotton is found by dividing the weight of a unit of length fed to the machine by that of a unit of length of the resulting lap, sliver, or other product. Thus the waste is accounted for.

In the case assumed above, it is plain that with a draught (or multiplication in length) of 4, the amount of cotton fed upon 54 inches will be found (neglecting waste) in 216 inches, or 6 yards of lap. Consequently, as the yard of lap must weigh 10 ounces, 6 yards must weigh 60 ounces, and this is the weight required to be spread upon each division of the creeper; hence the

Rule.—Multiply the weight per yard of the lap by the length in yards of the divisions on the spread-board, and the product by the draught, as in example given, $10 \times 1\frac{1}{2} \times 4 = 60$.

Calculations with regard to laps are usually in terms of ounces or grains per yard, but sometimes what is called the "hank" of a lap is required, although such a form is not often of much use. The "hank" of a lap, or sliver, or rove, or yarn, means the number of hanks, of 840 yards each, of the given lap, etc., which are in one-pound weight. Of course, in the matter of laps this number is always a very small fraction, and is expressed by a small decimal. In its calculation it is well to remember that there are 7,000 grains in a pound-weight, and that therefore if 1 hank of 840 yards weighs a pound—which would signify that the rove was a "1-hank rove"—12 yards weigh 100 grains. Therefore, if there were 2 hanks to the pound, 12 yards would weigh 50 grains, and the hank is always to be found by the following

Rule.—Divide 100 by the weight in grains of 12 yards, and the result is the hank required.

Let this be applied to the case of 10 ounces per yard; then $10 \times 12 \times 437{\cdot}5 = 52{,}500$ grains in 12 yards, and $100 \div 52500 = \frac{1}{525} = 0{\cdot}0019$, which is the required hank. If the lap had been 1 ounce per yard, the hank would have been 0·01905, and hence the further

Rule.—Divide 0·01905 by the weight per yard in ounces; the result is the hank.

This process is quite applicable to any of the forms of the material; but, of course, in sliver the unit of weight is a grain, and in the yarn the unit of length is best assumed as 1 lea, or 120 yards. In the latter case the rule becomes, when altered accordingly, divide 1,000 by the weight of 1 lea in grains, and the result will be the hank required. At the proper places will be found short tables of the weights and hanks of slivers, rovings, and yarn, which it is hoped will be found useful. In all calculations which have for their object the yarns, sliver, etc., back to the cotton, it is very necessary to take account of the amount of waste, which has been omitted in the calculations given above. This is greatly facilitated if a series of tests be occasionally made, as fresh cotton is introduced, passing a weighed quantity through each of the processes up to and including the carding, and the results entered in a book and carefully preserved for reference. The question of waste is an important one, and much depends upon the judgment of the manager as to when the cotton has been sufficiently opened or carded to suit the quality of yarn required. In the various opening processes the waste may reach a total average of about 7 or 8 per cent. in cotton used for medium counts, but may often be 10 per cent. or more with inferior classes of cotton.

PROJECTION.—VI.

[*Continued from p.* 276.]

SECTIONS OF SOLIDS BY PLANES (*continued*).

THE following problem often occurs in mechanical drawing:—

A connecting rod has a rectangular butt-end, united to the cylindrical part by a circular fillet. Draw plan and elevation.

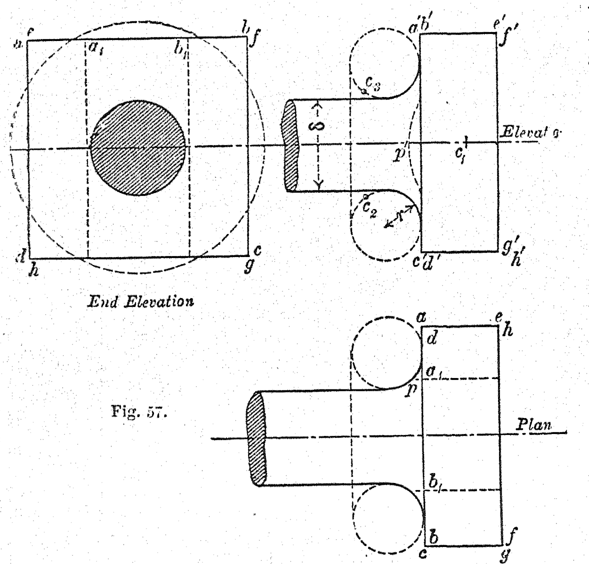


Fig. 57.

If the length of A B and B C of the butt at right angles to the axis of the rod be greater than $\delta + 2r$, δ being the diameter of the rod and r the radius of the fillet, the plan and elevation will be as shown in Fig. 57.

But if one side, $A_1 B_1$, be shorter, as represented by the dotted lines in Fig. 57, the elevation of the intersection of the fillet with the plane face will be a curved line. In this case the problem is a simple case of the preceding problem. The surface of the fillet is an annulus, the projections of the complete annulus being represented by dotted lines (Fig. 57). In Fig. 58 the construction is shown, the reference letters being the same as used in Fig. 56.

If the width of the butt be equal to the diameter of the rod, the projections will be as shown by the thick dotted lines (Fig. 58).

In making a working drawing of a connecting rod like that in the preceding problem, it is usually not worth while to go through the exact construction there given. The following is then the method to be used by the draughtsman:—Draw the plan and elevation (Fig. 57). Let p be the point of intersection of the straight side and circular fillet in the plan. From p project p' to the centre line of the elevation. Then a circular arc of any convenient radius may be drawn through p', the centre c_1 of the arc lying on the centre line of the rod. Two other arcs of the same radius, and with centres c_2 and c_3 found by trial, are drawn touching the first arc and the straight line $a' c'$. The dotted curve in the elevation (Fig. 57) is the result.

OBLIQUE PLANES.

In the previous lessons we have met with planes, chiefly as forming the boundaries of solids. The face of a solid is only a portion of the plane; and the boundary of the face, being given by its projections, defines the position of the plane of which it forms part. However, this method of representing a plane by drawing the projections of points or figures in it is inconvenient when we are dealing with the plane in its most general sense—that is, a flat surface extending indefinitely in all directions.

Traces of a Plane.—Any two planes which are not parallel to each other, intersect each other in a straight line. Any plane, therefore, will cut the horizontal/vertical plane in a straight line, which is called the horizontal/vertical trace of the plane. This statement may be made to

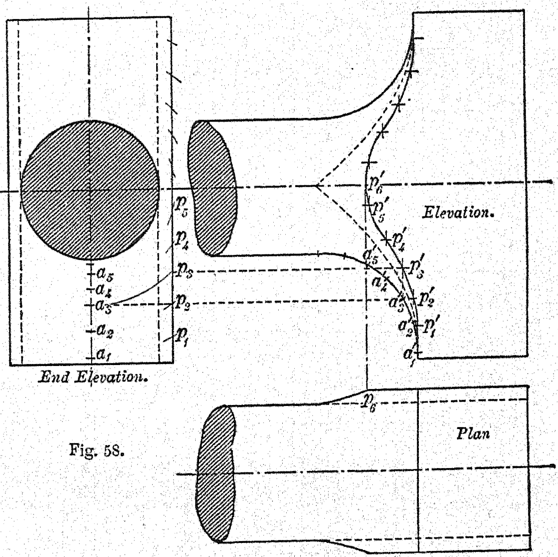


Fig. 58.

include the case of the given plane being parallel to the $\frac{\text{horizontal}}{\text{vertical}}$ plane, if we say that the $\frac{\text{horizontal}}{\text{vertical}}$ trace is infinitely distant, or is at infinity.

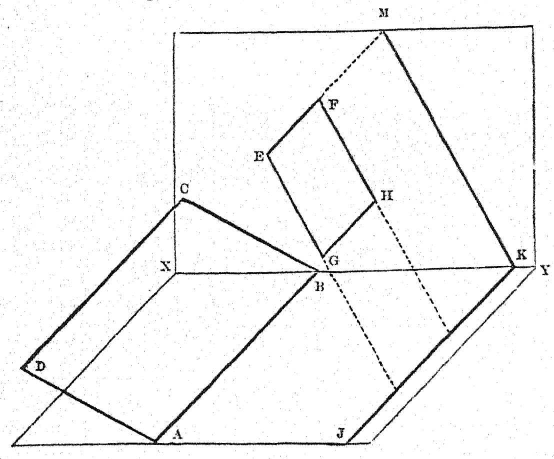


Fig. 59.

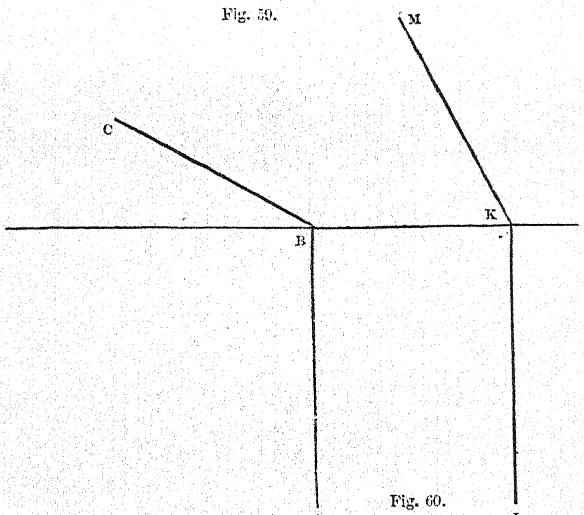


Fig. 60.

Representation of an Oblique Plane by its Traces.—Fig. 59 is a representation of the horizontal and vertical planes in position, and two oblique planes, A B C D and E F G H. The intersection of the former with the $\frac{\text{horizontal}}{\text{vertical}}$ plane is $\frac{\text{A B}}{\text{B C}}$; $\frac{\text{A B}}{\text{B C}}$ is therefore the $\frac{\text{horizontal}}{\text{vertical}}$ trace of the plane A B C D. The plane E F G H, if produced, would cut the $\frac{\text{horizontal}}{\text{vertical}}$ plane in $\frac{\text{J K}}{\text{K M}}$, which is therefore its $\frac{\text{horizontal}}{\text{vertical}}$ trace. If the co-ordinate planes are folded, as explained in Fig. 4, the traces of the two planes will appear, as in Fig. 60.

The horizontal plane, the vertical plane, and the plane A B C D (Fig. 59) have the point B in common. The three lines of intersection of these three planes are B A, B C, and X Y, which all meet at B. We see, therefore, that the traces of a plane must intersect on the X Y.

We will denote the point on the X Y at which the traces meet by the letter f, the vertical trace by $v'f$, and the horizontal trace by $f\,h$. The planes represented in Fig. 60 are each at right angles to the vertical plane, but inclined to the horizontal plane. The plane shown at b (Fig. 61) is at right angles to the horizontal plane (that is, it is vertical), but inclined to the vertical co-ordinate plane. The plane shown at c (Fig. 61) is at right angles to both planes of projection. The planes shown at d, e, and f are inclined to both planes of projection. In the oblique plane (Fig. 61 f), the point of intersection of the traces is infinitely distant on X Y.

The student should bear clearly in mind that the vertical trace V F of an oblique plane is a line in space whose elevation is represented (in the cases shown, Fig. 61) by $v'f$, and whose plan coincides with X Y. Similarly the horizontal trace F H is a line in space, its plan being $f\,h$ and its elevation coinciding with X Y.

The traces are supposed to extend indefinitely in both directions; thus, Figs 61 a and 61 b represent the same plane.

The angle between two planes is the angle between two straight lines drawn, one in each plane, from a point in their line of intersection at right angles to it.

Problem 1.—Given the traces of a plane, to determine its inclination to each of the co-ordinate planes.

Let $v'f$, $f\,h$ (Fig. 62) be the given traces. Take any point, A, on the horizontal trace, and on the given oblique plane in space draw the line A B at right angles to the horizontal trace. The plan, $a\,b$, of this line will also be at right angles to the horizontal trace. Then, evidently, the inclination of the oblique plane $v'f\,h$ to the H.P. is the angle between the line A B and its plan, $a\,b$; *i.e.*, the inclination of the plane $v'f\,h$ is the same as the inclination of the line A B. Suppose now that the line A B is drawn of such a length that B lies on the vertical trace; then b lies on X Y, and b' on $v'f$. The elevation of

A is, of course, also on the X Y. The problem is now reduced to finding the inclination to the H.P. of the line A B given by its plan and elevation, $a\,b$ and $a'\,b'$, and can be solved by the method shown in problem 3, page 209.

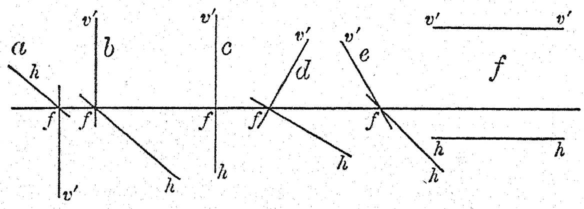


Fig. 61.

The following method is more suitable, however, for this particular case:—Consider the line A B in space to lie on the surface of a cone with vertical axis, the point B being the vertex, and the point A lying in the circular base of the cone. Then every straight line lying on the surface of this cone has evidently the same inclination to the H.P. as A B. With centre b and radius $b\,a$ describe a circle cutting the X Y in a_1 and a_2. Join b' to a_1 and a_2, $b'\,a_1\,a_2$ is the outline of the elevation of the cone, and therefore the angle $b'\,a_1\,a_2$ is the required angle of inclination of the plane $v'\,f\,h$ to the H.P.

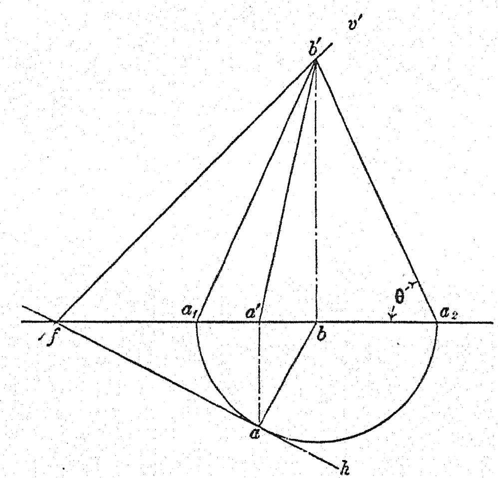


Fig. 62.

Fig. 63 shows the construction for finding ϕ, the inclination of the given oblique plane to the V.P., and is as follows:—Let $v'f$, $f\,h$ be the given traces of the plane. Take any point b in $f\,h$, and from it draw $b\,b'$ perpendicular to X Y. With centre b' draw a circle touching $v'f$, and cutting X Y in a_1. Join $a_1\,b$. The angle $b\,a_1\,b'$ is ϕ, the required inclination of the given plane to the vertical plane of projection.

The constructions in Figs. 62 and 63 are *co-ordinate;* and the student being given one, should be able at once to write down the other. In future, only one of two co-ordinate construction will be given, but the student should in all cases work out the other for himself.

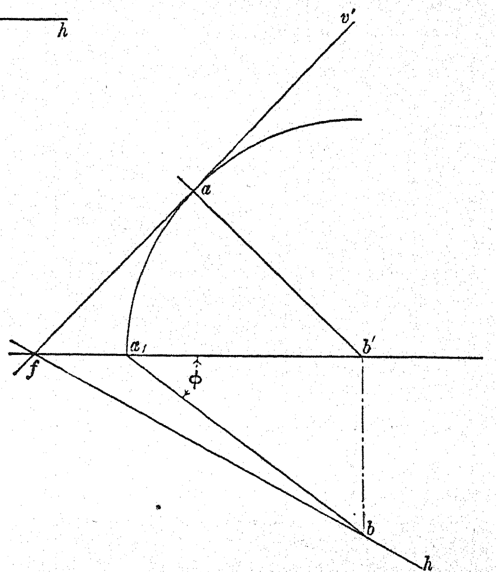


Fig. 63.

WATCH AND CLOCK MAKING.—VI.

By David Glasgow,
Vice-President of the British Horological Institute.

[*Continued from p.* 296.]

CHRONOMETER AND WATCH MAKING (*continued*).

Fixing Movement in Case.—As the largest portion of English watches are made with what are called "double-bottom" cases—*i.e.*, cases having the inner cover, or bottom, made solid with the middle—the only way of fixing in the movement that will permit of it being opened to view the works is with a joint and bolt; but there are so many objections to this arrangement that it is difficult to account for its continuance.

Now that a large number of keyless watches are made with single bottoms to the cases the bolt and joint are of necessity used to fix the movements in the cases, but there are not the same objections to

these as to the double bottom full-plate, as there is no necessity to open the bizzle to set the hands in keyless watches.

It is not usual to let the finisher have the case, as it can be sprung and polished, etc., while the watch is being finished, and, if the watch has a dome case, it is necessary to fit the movement to it first. The best way to fix it is with one pin and one screw; two pins and a screw are sometimes used, and this may be done if the edge of the case where the pins go is deep enough to take pins of sufficient strength, but this is seldom the case. A good-sized hole is drilled in the edge of the pillar-plate close to the step, and a piece of brass is tapped and screwed into it, projecting a very little beyond the edge of the plate; this piece is filed and the sides of it shaped with a chisel into the form of a wedge, when the position of the dial in the case is marked on the flange of the case which supports the frame, and a square notch is cut in it to receive the thick part of the pin, and prevent the frame from moving round in the case, while the wedge-shaped end of the pin projects underneath it, and prevents the frame from rising from the case. A mark is then made for a screw on the top plate opposite the wedge, and drilled close enough to the edge of the plate for the head of the screw to come over the band of the case, and a dog-screw (*i.e.*, a screw with a portion of the head cut away) fitted; this screw is screwed into the pillar-plate, the body going through a hole in the top plate into which its head is sunk as deeply as the thickness of the band of the case will admit of. The sink in the plate must be a very little below that in the band, and the screw should have a shoulder to rest on the pillar-plate while the head grips the band of the case sufficiently tightly to prevent any movement of the frame in the case. I have found this the most convenient and simple way of fitting a movement to a case, as, if it is properly done, the movement can be removed or put in the case with the greatest ease. In putting it into the case, if the movement is moved round, the wedge will drop into the notch, and, by turning the screw half round, the movement is secured. Care must be taken to find a place for the screw that will be free from the other parts of the watch; in ordinary fusee movements, between the figures seven and eight on the dial will be the best place for the pin, and there will be room for the screw opposite.

JEWELLING WATCHES.

Objections to Jewelling.—Jewelling the holes for watch pivots has been practised for nearly two centuries; it was invented by Nicholas Facio, a native of Geneva. He came to London in 1700, and a few years later commenced the business of watchmaking and watch-jewelling in partnership with the brothers De Beaufré. The watchmakers of Paris, to whom he first applied, not appreciating his invention, gave him no encouragement, and the London watchmakers do not appear to have treated him with much greater liberality, as the Clockmakers' Company opposed his application for a patent, although, presumably on the strength of his invention, he had been admitted as a member of the Royal Society.

Stones for Jewelling.—The stones used for jewelling watches are the ruby, sapphire, chrysolite, and garnet; a thin rose diamond is generally put as an end-stone to the balance cock of English watches, but only as an ornament, and that is the only diamond ever used in the jewelling of a watch.

There are great varieties of all these stones, so that it cannot be said that a ruby is best for a hole unless it is the right sort of ruby, and colour is not always a guide as to the quality: the oriental ruby is the best, being the hardest and having the greatest specific gravity; it should always be used for the best watches. Sapphire is usually used for the holes of marine chronometers. Rubies that have a deep red colour are prized and used by the Swiss, while in England the milky stone is preferred, as being harder; it is also thought that, in consequence of the colouring matter, the red stones blacken the pivots more than the light-coloured ones.

My own experience is that, if the stone is hard and well polished, the colour is not of much consequence; since, although the pivot becomes black, it does not cut, and the discoloration is easily removed with a peg and a little fine red stuff.

The quality of the oil has much to do with the blackening of the pivots, and those which have the greatest friction will become discoloured first. In ordinary watches jewelled in the third and fourth wheel holes, the lower third wheel pivot will be the blackest, it having the greatest friction, from being so close to the action of the centre wheel in the pinion; and if the centre holes be jewelled, the bottom pivot will generally be found more discoloured than the top one from the same cause. But there are so many reasons in favour of good jewel holes that every good watch should have all the train holes jewelled except those of the fusee, which are expensive, and liable to be broken with the pressure in winding the watch. Garnet is largely used for jewelling common watches, especially in the pallets to lever escapements; it is of the same hardness as chrysolite, but not so brittle. These pallets are soon cut, a few years' wear pitting

the face of the stone on which the escape-wheel tooth drops, in which case the only remedy is new pallets, as to polish out the pits would spoil the escapement. Chrysolite would answer better for pallet stones. Garnet is also used for the impulse pins of lever escapements, but the least violent external motion to the watch will break off the pin, if the balance be a heavy one, and the cost of replacing it will be many times the difference between the original price of a ruby and a garnet pin.

Watch-jewelling in England has hitherto been divided into two branches only—namely, hole-making and jewelling: the hole-maker flatting and drilling the stone, and turning it true on the edge and faces; and the jeweller fitting the hole to the pivot, shaping and polishing it, and setting it in the plate. In Switzerland there is a great division of labour in preparing and fitting the holes to watches. Jewelling would seem to be as far removed from escapement-making as two branches of a trade could be, but the Swiss escapement-maker is served with the jewel holes along with the other materials for the escapement, and sets them himself. This practice would be useful to watch jobbers going to India or the Colonies, but watch-jewelling is much of a specialty, and requires great practice to do it well.

Hole-making.—The English process of making a hole is to take the rough stone, about the size of a small pea, and hold it against the face of a plate or mill fixed in the lathe and rotated rapidly; the mill is of soft iron charged with diamond powder. When one side of the stone is flatted, the other side is held against the mill until the stone is brought to the required thickness; it is then cemented on to a chuck, turned true on the face and edge with a piece of black diamond fixed in a handle, and centred with a small splint of the same, and drilled to half the length of the hole: the stone is then reversed on the chuck, the face turned true, and, if it is the front of the hole, the chamfer or cup is turned out of the centre, and the hole met. From first to last this seems a very slow process; and flatting the stones is a very dirty one, as the mill must be kept supplied with plenty of water. In fact, I believe it is the identical method pursued by Facio, the inventor. When the hole is a large one, the process of drilling with a diamond point is well enough, and it is acknowledged that holes made in this way cannot be beaten; but, without adopting all the Swiss system, which has some drawbacks, I think ours ought to be greatly improved.

The Swiss flatten the stones on a large horizontal mill driven at a very high rate of speed, generally by a turbine, or by steam power. The stones are not presented singly to the mill, but are cemented on to a block, and held against it in quantities of some dozens at a time; when the stones are sufficiently reduced on one side, they are reversed, and the other side ground until they are the required thickness. It is evident that this operation can be done for a tithe of what it would cost to have them flatted by the old process.

The uncertainty of getting the sides parallel to one another by the above method, however, prevents the holes from being drilled perpendicular to one of these sides. If they were drilled one at a time this could be done, but the stones are pushed half a dozen or more into a kind of tube or holder, which is fixed on the rest of the lathe in a line with the drill in the chuck. This drill, instead of being a diamond, is a piece of drawn steel wire; it goes through a great many stones at one time, and is charged with diamond powder, and, instead of a man or woman drilling one hole and then stopping the machine, he or she has to attend to six machines, each drilling six holes at one operation, and the faces of the holes not being parallel to one another, the holes are seldom perpendicular to either side of the stones. If they are much out it is not possible by any process of opening to make true holes, especially if they are a good length; but this process of flatting and drilling is so expeditious, and consequently cheap, that jewelling an extra pair of holes makes little or no difference in the price of a Swiss watch, and jewelling every hole is now the rule with them, although, as before stated, they are not always as good as brass ones. They are made very thin, are very badly polished, and of such material that they are easily broken, and few common Swiss watches are without a cracked jewel hole or two. There is no reason why we should not take a leaf out of the Swiss book, and amend our system without altogether adopting theirs. A Swiss jewel hole maker informs me that thirty years ago, before the drilling in quantities was adopted, a woman or lad could drill a hundred flatted stones in a day, and the holes in these stones were required to be perfectly perpendicular to one side of the stone, although the rate of speed that a boy or woman could drive a foot-lathe would be much too slow for a revolving drill; but this process would seem a great improvement on ours of setting up a stone in a lathe, and meeting a hole small enough for a staff pivot.

Jewelling.—When the jeweller first gets the frame to jewel the holes for the escapement, he has nothing to do with fitting the pivots, as they are not then made, but he should have a size given him, and his care should be to make use of all the thickness of the plates for holes with end-stones, to

make the sinks in which the settings rest quite square, and the shoulders of the settings to coincide with the sinks. The setting itself should have some substance in it, and not be turned away so thin that any extra pressure on the end-stone would bend it in and reduce the end-shake, or until it is impossible to lift the hole, unless it is done as the jeweller does it, on the end of a damp finger. Some watchmakers object to large stones on the ground that the colouring matter being in a greater body than in a small one, it will blacken the pivot more; but then, on the other hand, it should be remembered that a small stone means necessarily a weak one, and a large stone has other good qualities as well as strength. When there are end-stones, the oil chamfer is cut at such an angle in a thick stone that the pivots drop into their places without trouble, and without the risk of injuring them in putting the watch together—a thing that is so often happening to the pivots of the balance staff, especially where the balance is a heavy one. Some jewellers make a double chamfer to the holes, but I see no use in that.

There has been considerable difference of opinion amongst watchmakers as to the best shape of a hole: some have advocated a long straight hole with a pivot, largest at the extreme end to lighten the friction; but no person who has had much experience of the going of watches would think of making a balance-staff pivot unnecessarily weak, and of the very form most liable to injury. A jewel hole should not be straight, but rounded from both ends to the middle, so that the rubbing surface shall be small and equal, whatever the amount of end-shake may be, as shown in Fig. 8. This is also the best shape for thorough holes (*i.e.*, holes without end-stones), although they are seldom made so.

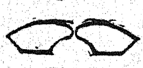


Fig. 8

English jewellers have persistently used screws with too small heads and too large taps for fixing jewel holes with end-stones. There is no advantage in a large screw where there are only three or four turns of thread on it, and jewel screws seldom get broken; occasionally half the head comes off if it has been slit down too much. The objections to large jewel screws are that, in order that the heads may come over the setting, the holes have to be drilled so close to the sink in the plate that in many instances they burst out, and if, from overheating the screw in hardening, a scale is left, or any other accident happens from carelessness on the part of the examiner, etc, and the thread of the hole is injured, the hole cannot be tapped over again with a larger tap, as could be done should this occur with a small hole. I have seen many watches almost new, that purported to be good ones, with several of the jewel screws overturned and quite useless, and this must have been the case before they left the maker's hands. This is especially the case with the jewelling of escape-cocks that have end-stones. Unless the cocks have ample thickness, and can be properly jewelled, they would in most instances be much better with thorough holes.

It is now, however, the fashion to put end-stones to the escape-cocks, very often where there is insufficient room for them (and where, in consequence of the want of room, the work would be unsound, even if well done), because end-stones are characteristic of good work, and one sometimes sees an end-stone to the escape-wheel, with the pallet staff in a brass hole. First-class jewelling costs nearly as much in Geneva as it does in London, notwithstanding the superior methods the Swiss have of flatting and drilling the stones, as opening, setting, and polishing the holes require much greater skill and labour than making them. The holes are opened with copper wire and diamond powder, and polished with diamond powder on a hard dog-wood peg, and a hole requires a good deal of labour with the latter before it is properly polished. I find that now the factories are jewelling their own watches, but I do not know how far they have adopted the Swiss system of hole-making; the work, however, admits of improvement.

Snailing.—There is the objection to polishing brass surfaces such as great wheels and barrel covers that, although they are somewhat difficult to polish, they are easily scratched, and that brushing spoils their appearance. The art of spotting such small pieces by hand is not easily acquired, and gilding great wheels and barrels with teeth on them has proved so ruinous to the work by softening the brass that it is rarely resorted to now. Snailing is a very old method of finishing the steel caps of fusees, but since the introduction of keyless work it has come more into use, it being the usual way of finishing the steel winding wheels. The tool usually employed by finishers by which they perform the operation is a very primitive one, mostly consisting of a copper penny driven on to a good-sized arbor, and termed a mill. The copper is turned away from the side of the roller that is to be used until a thin rim only is left projecting at its outer edge; the roller is fixed in a pair of small turns which are fixed to the rest holder of a larger pair by a projecting shank; the work that is to be snailed is put into the large turns, and the snailing roller brought close to it. One of the runners of the small turns is excentric to the other, and by turning this runner round, the roller is brought

into contact with the top side only of the wheel to be snailed ; if the faces were parallel to each other, the curves made by the roller coming in contact with the work would be crossed and obliterated by the roller when leaving it, even if the arbor turned only in one direction. This effect is to some extent produced by using a bow, as the up strokes of the bow make curves in a contrary direction to those made by the down strokes, but this confusion of circles does not matter very much, as when it is found that the roller has been in contact with every part of the work, and that it is smooth, the snailing is done with the down strokes only, a long bow being used, and the snailing roller held in the fingers and prevented from turning, while the bow is pushed upwards. Emery and oil mixed with sharp stuff is recommended with the copper roller, but copper is too soft and a bad material for a roller, as the emery sticks in it, and it is difficult to get a smooth surface with it or without deep races in it; the roller should be made of hard brass, and the emery should be washed until it is very fine, and no sharp stuff used with it. Brass wheels, etc., should be stoned free from scratches, and got quite flat on arbors. For this purpose a roller made of hard box-wood should be used with oilstone dust ground as fine as possible, and mixed with oil to the consistency of cream, and the polishing power used sparingly. Sharp stuff and oil gives a bright surface on brass, but polishes too much, leaving the circles undefined. Rollers of any size may be used; one twice the diameter of the object snailed makes a curve that looks very well.

Snailing is a very excellent way of finishing great and motion wheels, and the bottoms and covers of barrels, and if done as directed, they will brush bright and clean without showing any scratches. Although it is in universal use, the tool described is obviously only a makeshift.

If polishing should be made a special branch of watch finishing, snailing might be well done without the application of very great skill by using a proper tool, adapted to either a foot-lathe or a hand-lathe, or throw, with a rotary motion, with a screw for the adjustment of the angle of the roller. As the snailing roller will not go right to the centre of a wheel, but would leave a lump there, a hollow is usually cut close to the centre and polished; this gives a little variety and relief to the work.

Although the progress of the factory system of watchmaking has been very marked during the last few years, there does not seem to be any improvement on the old process of snailing, as I find the work done in any of the factories inferior to that done by the watch finishers with their old appliances.

PHOTOGRAPHY.—VI.

By T. C. Hepworth, F.C.S.

[*Continued from p.* 288.]

THE DARK ROOM.

The photographer requires, besides a studio or glass room, one in which he can develop his plates, and do such other work in which the absence of ordinary white light is the chief desideratum. This apartment is called the dark room, and although, under stress of circumstances, a mere cupboard is often dignified by the name, it is far better if possible that the worker should have plenty of space in which to carry on the very important operation of development. Ventilation must, for one thing, be seen after, for one at least of the chemicals employed gives off a vapour which is injurious—we mean ammonia.

The room is called dark, but, of course, it is not really so, or any work would be impossible; the light which is used is filtered through some kind of red medium to make it as harmless as possible to the sensitive compounds with which the photographer deals. If the room has a window, it is best to close it up with opaque material, with the exception of a space about two feet square, and this space may conveniently be furnished with three frames filled in with different shades of coloured material. The first, which may be a fixture, should be ruby glass, while the two others, each made to slide in grooves in front of it, may be canary and ruby medium respectively. (These are sold for the purpose, and represent a kind of semi-transparent calico.) The need of these three frames is found in the circumstance that daylight varies much in its intensity according to the time of day and the season of the year. Should the sun be actually shining on the window, the light filtering through all three media will be hardly safe for the most sensitive plates, while perhaps later in the same day the ruby glass alone will be quite sufficient protection.

As an auxiliary to daylight, the dark room should be furnished with a good lamp. A gas lamp fixed outside the red window, and protected from wind and weather, is a good arrangement, particularly if the tap be so arranged that it is within easy reach of the operator's hand, so that he can turn it up or down according to his requirements. Failing this, there are several good lamps sold for the purpose, and fitted for either gas or oil. The gas is to be preferred both because of its cleanliness, and for the ease with which its flame can be regulated, as just pointed out.

The principal feature of the room will be a sink fitted with a water tap and discharge pipe. This

should be of liberal dimensions, and of glazed stoneware by preference. The tap should be at a height of about one foot above it, and should be furnished with a rose as well as an ordinary outlet, so that a flood of fine spray can be urged upon a photographic plate when desired. Compound taps of this description can be purchased. The sink should be placed beneath the window, so that the worker can see what he is about. Half of the sink may conveniently be occupied by a wooden grill, upon which dishes, etc., can be placed under the tap, and this grill can be so made that it will slide to the right or the left as desired. Shelves for bottles, a table, racks for dishes, etc., will complete the necessary furniture of the dark room.

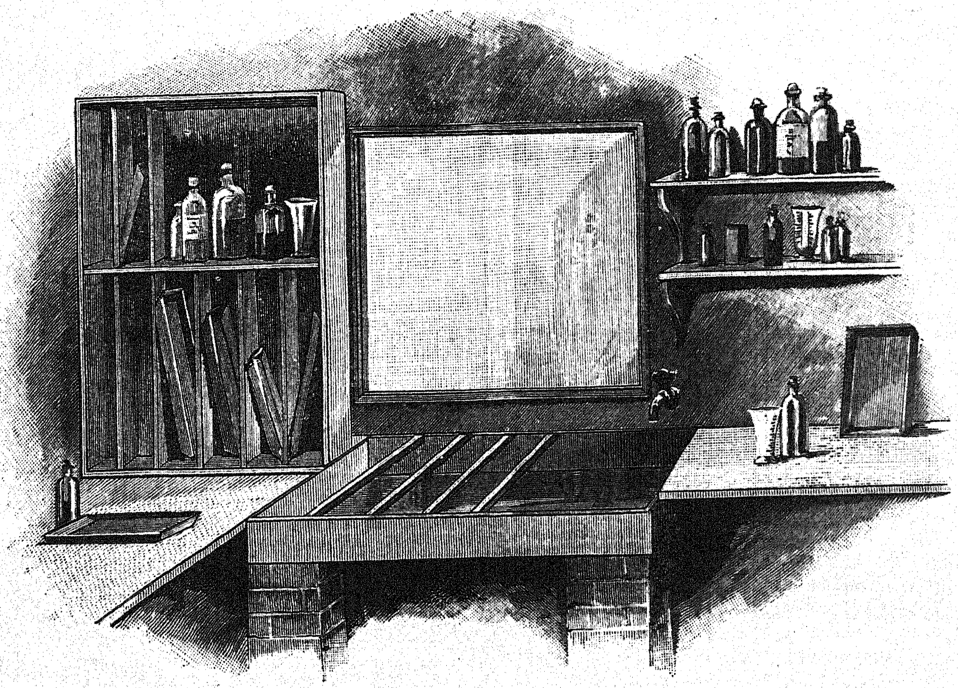


Fig. 42.—A Dark Room.

There should be enough light to enable the worker to find his way to every corner of the room without difficulty, and there is no necessity for any stint in this respect, provided that the light is of the right kind. Many workers are far too cautious in this respect. We have seen dark rooms which are so devoid of illumination that it is quite impossible to watch the progress of development, and under such conditions it is next to impossible to turn out good negatives. This need not be so, especially as it is such an easy matter to test the light for quality. One has only to expose a plate half covered by a card for a couple of minutes to the light employed to find out whether it is safe or not. If such a plate, on development, shows trace of light action, more protection is needed, but if it remain clear, the light may be considered satisfactory. One caution is, however, necessary: the red and orange media will not preserve their non-actinic qualities for ever, but will gradually deteriorate. Hence, although they may at first prove a sufficient protection, they will, after a couple of seasons' use, become more or less bleached, and should be renewed. The red glass does not alter in the same way. As there is no means of making the light absolutely free from action on the sensitive plate, due caution must at all times be used in the manipulations, and whether plates be changed from one receptacle to another, or developed, every care must be taken not to expose them to the red light more than necessary. In developing, for instance, a cover should be at hand to place over the dish, except while it is being examined. The cardboard lid of a plate box will answer this purpose, but the careful photographer will provide one covered with black velvet, which will fit right over the dish. With such a cover he

can open the door of the room during a protracted development without any fear of spoiling his plate by the access of white light.

In choosing a lamp for the dark room, preference should be given to one of large dimensions, as the light is then more diffused by the ample surface of the panes of glass with which it is furnished. These should be of different shades of colour, so that the amount of light can be modified according to the work in hand. For example, a bromide of silver plate will require the protection of the darkest glass, while a chloride plate, such as is used for making a lantern slide, needs no more protection than a light yellow screen.

The stock bottles of mixed chemicals required are not many in number, and the fewer that can be managed with, the better. One most useful rule to observe in connection with these is that of careful labelling. Each bottle should not only be labelled with the name of the mixture which it contains, but the formula should also be included as well, so that when it is required to refill it, there need be no searching after a recipe, the exact source of which may have been forgotten. Besides, it is always as well to know the exact composition of any solution which may be used, so that it can, if required, be modified to meet special requirements. As an example of the kind of labelling recommended, the following may be cited :—

PYRO SOLUTION.

Pyro - - - - - -	1 ounce.
Potassium metabisulphite -	½ ounce.
Water - - - - - -	10 ounces.

In the illustration, Fig. 42, the general arrangements of a dark room are indicated with the window, sink, shelves for bottles, and racks for dishes. These arrangements will naturally be modified according to the space at the disposal of the worker.

DEVELOPMENT.

A gelatine plate which has been exposed to the action of light in a camera undergoes a certain change, but upon examining such a plate no change is apparent. It looks exactly as it did when first taken from its original box; but, nevertheless, a great change has occurred in the plate, although, for the moment, there is no visible evidence of it. Certain parts of the film have been acted upon more or less by the light, but these changes do not become manifest until the plate is submitted to the operation known as Development.

When a chemical solution called a developer is applied to the plate, those parts of the surface which have been affected by the light become blackened by the reduction of black opaque metallic silver, while those parts where the light has not acted remain unchanged. It is evident, therefore, that in a negative image everything is reversed—that is to say, in the case of a portrait, the white face, hands, and linen will appear black, and will come out before any other parts of the picture, as masses of dark reduced silver, while the black portions of the subject, such as the coat, etc., will in the negative be white. The same rule obtains in the landscape, where the brightest part of the subject, the sky, will be black, while the dark trees and other objects will remain little or not at all affected by the light. There are various developing agents, and the operator must be guided in a great measure in his choice of which to adopt by the particular work in hand. The most generally and widely employed developer, in this country at least, is that which owes its energy to Pyrogallol, more commonly known as pyrogallic acid, and commonly called for short "pyro." This, indeed, may be called the sheet-anchor of the photographer, and, although many other developing agents have been brought forward of late years, pyro still holds its own.

Pyrogallol, or pyrogallic acid, is an exceedingly light crystalline and feathery compound which is sold generally in one-ounce bottles. So light is it that this bottle would hold more than half a pint of water, yet when quite full it will accommodate but one ounce of the dry pyro. It is a very poisonous compound, and some caution should therefore be used in its employment. Mixed with water it will very quickly turn brown, owing to rapid oxidation, and therefore for use it is best mixed with some kind of preservative.

Each maker of plates advocates a developer which is said to work better with those particular plates than any other compound. But some of these formulæ are unnecessarily intricate, and, although they may have their merits, many of them are certainly not founded on any strict scientific basis. It is best to use 10 per cent. solutions for developing purposes, and then by very slight calculation the operator is able to make up any developing formula which may present itself. Thus, to make a 10 per cent. solution of pyro, and at the same time give it preservative qualities, we should mix, in about six ounces of warm water, half an ounce of metabisulphite of potash, and stirring this solution with a glass rod until the crystals are thoroughly dissolved we can pour it into the full bottle of pyro, when we shall find that the latter will almost instantaneously dissolve in the liquid. We may now pour this mixture into a fresh half-pint bottle furnished with a stopper, and fill it up with water to make up ten ounces. This bottle should be

labelled "Pyro 10 per cent.," and ten minims of the liquid will contain just one grain of pyro.

For pyro development we shall require two other stock bottles, one constituting the accelerator, and the other the restrainer. The accelerator is an alkaline solution which may be liquid ammonia, ammonia carbonate, sodic carbonate, or some other alkali; but, for the sake of simplicity, we will suppose that the operator decides upon adopting liquid ammonia as his accelerator. The strong liquid ammonia sold by the dealers is, in reality, a solution of ammonia gas in water, and is supposed to have a specific gravity of 880. But it is certain that ammonia solution is seldom of this strength unless when first opened, for it is continually giving off gas, as its pungent and suffocating smell indicates whenever the stopper is removed. Indeed, if the stopper be not fastened down by some special means it will often fly out should the temperature of the room in which it is kept be higher than usual. To make a 10 per cent. solution of this volatile compound it is merely necessary to pour into a ten-ounce bottle one ounce of the fresh liquid ammonia and fill up the bottle with water. It should then be labelled "Ammonia 10 per cent.," ten minims containing one minim of the liquid ammonia 880.

The restrainer is a solution of potassic or ammonic bromide, one ounce of either salt being dissolved in about six ounces of water, and made up eventually to ten ounces in a half-pint bottle. This bottle should be labelled "Bromide 10 per cent.," and, like the other bottles, ten minims will contain just one grain of the original substance.

DRAWING FOR CARPENTERS AND JOINERS.—VI.

[*Continued from p. 284.*]

ROOFS.

THE general principles of Building Construction being reserved for a separate series of lessons, it is not deemed necessary to follow the exact order in which a building would be erected, the object of the present lessons being improvement in *drawing*, whilst, at the same time, the principles of the construction of the subject of the study are given; so that the student may not simply learn to copy *lines*, but may understand the language of which such lines are the words and sentences.

The term roof seems derived from the Saxon word "hrof," or, perhaps, a contraction of the German words "Hier-auf" (upon here), and, as is well known, means the cover or top of a building, generally consisting of two sloping sides, though occasionally of other figures.

The ancient Egyptians, Babylonians, Persians, as well as other Eastern nations, had their roofs quite flat. The Greeks appear to have been the first who made their roofs with a slant each way, from the middle to the edges. This was very gentle, the height from the ridge to the level of the walls not exceeding one-eighth or one-ninth of the span, as may be seen by many ancient temples now remaining. In northern climates, subject to heavy rains and falls of snow, the ridge must be very considerably elevated. In most old buildings in Britain, the equilateral triangle seems to have been considered the standard both in private and public edifices, and this pitch continued for several centuries, till the disuse of what is called Gothic architecture. The ridge was then made somewhat lower, the rafters being *three-fourths* of the breadth of the building. This was called the *true pitch*; but, subsequently, the half-square seems to have been considered the true pitch.

The heights of roofs were gradually depressed from the half-square to one-third of the width, and from that to a fourth, which is now a very general standard, though they have even been executed much lower.

There are some advantages in high-pitched roofs, as they discharge the rain with greater facility; the snow continues a much shorter time on the surface, and they are less liable to be stripped by heavy winds. Low roofs require large slates, and the utmost care in their execution; but they have the advantage of being much cheaper, since they require timbers which are shorter and of less scantling. When executed with judgment, the roof is one of the principal ties to a building, as it binds the exterior walls to the interior and to the partitions, which act like strong counter forts against them.

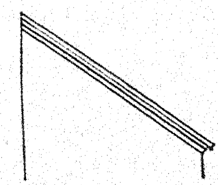


Fig. 83.

Roofs are of various forms, according to the nature of the plan, and the law of horizontal and vertical sections. The most simple form of a roof is that which has only one row of timbers arranged in an inclined plane, which throws the roof entirely on one side; this is called a "lean-to" or shed roof (Fig. 83).

The most general roof for an oblong building consists of two rectangular planes of equal breadth, equally inclined, and terminating in a line parallel to the horizon. Consequently, its form is that of a triangular prism, each side being equally inclined

to the plane of the wall-head; this is generally called a "pent roof" (Fig. 84 is the end view, or "gable," and Fig. 85 is the plan of such a roof).

Roofs flat on the top are said to be *truncated*. These are chiefly employed with a view to diminish the height, so as not to predominate over that of the walls.

When all four sides of the roof are formed by inclined planes, it is called a "hipped" roof (Figs. 86 and 87), in which case two of the inclined sides

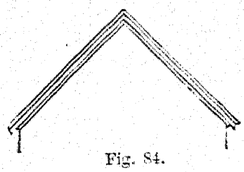


Fig. 84.

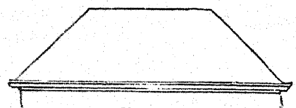


Fig. 86.

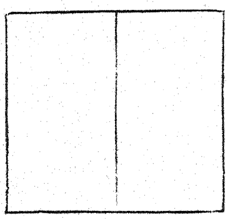


Fig. 85.

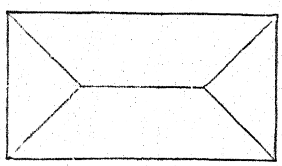


Fig. 87.

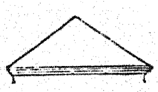


Fig. 88.

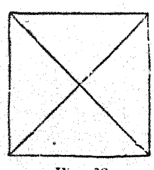


Fig. 89.

—namely, those which slant from the long sides of the building—will be *trapezoids*, and the other two *triangles*.

But if the building to be covered be *square* (Figs. 88 and 89), and all the sides slant equally, the roof will form a square pyramid, for the projection and development of which *see* "Projection."

When the planes of roofs, instead of being continued until they meet in a ridge, take another slant at a certain height, they are called "curb" or "Mansard" roofs (Fig. 90), from the name of their inventor, a great French architect who lived in the sixteenth century. They are much employed in France, and are hence often called French roofs. When the plan of the roof is a regular polygon, or a circle, or an ellipse, the horizontal sections being all similar

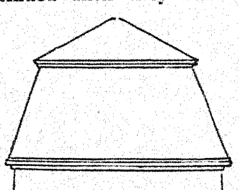


Fig. 90.

to the base, and the vertical section a portion of any curve, convex on the outside, the roof is called a dome.

COMMON TERMS.

Wall-plates are pieces of timber laid on the wall in order to distribute the pressure of the roof equally, and to bind the walls together. Were it not for wall-plates, the tie-beams of a roof or the joists of a floor would rest on single bricks, whilst the spaces between the joists would not in any way assist in bearing the load. The wall-plate lying on the whole length of the wall, therefore, spreads the pressure over all the bricks, and the trusses, or joists, rest on a frame of timber.

Trusses are strong assemblages of timber, generally of a triangular form, serving to support the purlins on which the common rafters rest. They are disposed at equal distances, and are used when the expansion of the walls is too great to admit of common rafters alone, which would be in danger of being bent or broken by the weight of the covering for want of some intermediate support.

They are variously constructed, according to the width of the building, the contour of the roof, and the circumstances of the walling below.

Tie.—Any piece of timber connected at its extremities to two others acted upon by opposite pressures, which have a tendency from each other, or to extend the tie as a rope or chain.

Straining-piece.—A piece of timber connected at its extremities to two others acted upon by opposite forces, which tend to press them together. The straining-piece, by being placed between them, serves to keep them apart, and, further, acts as an abutment for the external pressure.

Hence, a tie and a straining-piece act in a manner exactly opposite to each other—the one draws the ends of two pieces of timber *together*, the other keeps them *apart*. A rope, chain, or iron rod could be used for the tie; but the straining-piece, which has to bear end-pressure, must always be stiff and inflexible.

Principal Rafters, or, as they are sometimes called, "principals," are the two pieces of timber which form the sides of a truss; their lower ends being mortised into the end of the tie-beam, or resting in an iron shoe, whilst their upper ends abut on and support the head of the king-post.

Purlins.—Horizontal pieces of timber resting upon the principal rafters, and at right angles to them; they pass from truss to truss, and across these again are laid the

Common Rafters, which are pieces of timber of a

smaller section, placed at equal distances across the purlins, parallel to the principal rafters. They support the boarding or battens to which the slating is fixed.

The *Tie-beam* is the horizontal piece of timber which forms the base of the triangle or other figure of which the truss may consist. As already mentioned, it receives the ends of the principal rafters, and is strapped up to the king- or queen-posts. The tie-beam answers a twofold purpose—viz., that of preventing the walls from being pushed outwards by the weight of the covering, and of supporting the ceiling of the room below. In some cases it is found desirable not to place a tie-beam at the foot of the rafters, but to use it as a connecting link higher up, something like the horizontal line in the letter A; in this case it is called a *Collar-beam*.

King-post.—This is an upright piece of timber in the middle of the truss. The principals abut against its upper end, and the tie-beam is strapped or bolted up to its lower end, and thus abutments are formed for struts, which give support to the principals in points between the tie-beam and the king-post.

Queen-posts.—Upright pieces of timber, framed above into the principals, and supported by a straining-piece or strut, whilst to their lower ends the tie-beam is bolted or banded up at points between the wall-plates and the king-post. Some trusses are constructed without king-posts, queen-posts only being used.

Struts are oblique straining-pieces, framed below into the king- or queen-posts, and above, into the principal rafters, which are supported by them; or, sometimes, they have their upper ends framed into beams which are too long to support themselves without bending. They are often called *braces*.

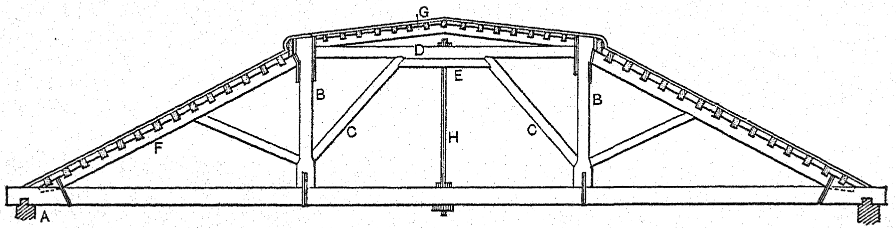


Fig. 91.

Puncheons are short transverse pieces of timber fixed between two others for supporting them equally. They are sometimes called *studs*.

Straining-beam.—A piece of timber placed between the queen-posts at the upper ends, in order to withstand the thrust of the principal rafters.

Straining-sill.—A piece of timber placed between the lower ends of two queen-posts, upon the tie-beam, in order to withstand the force of the braces, which are acted upon by the force of the covering.

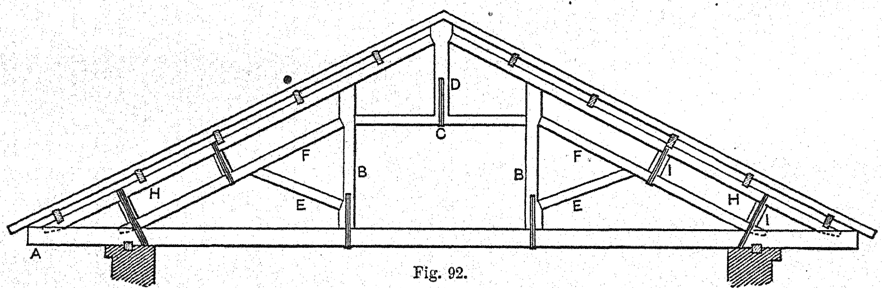


Fig. 92.

Camber-beams.—These are horizontal pieces of timber, made sloping from the middle towards the ends on the upper edge. They are placed above the straining-beam in a truncated roof, for fixing the boarding on which the lead is laid. Their ends run three or four inches above the sloping plane of the common rafters, in order to form a roll for fixing the lead. This is shown in Fig. 91, which is the roof-truss of the chapel of the Royal Hospital at Greenwich, constructed by Mr. S. Wyatt.

Auxiliary Rafters are pieces of timber framed in the same vertical plane with the principal rafters, under, and parallel to them, for giving additional support when the extent of the building requires their introduction. They are sometimes called *principal braces*, and sometimes "cushion rafters."

Joggles.—The joints at the meeting of struts with

king-posts, queen-posts, or principal rafters, or at the meeting of the rafters with king- and queen-posts. *The best form is that which is at right angles to the length of the struts.*

Cocking, or *Cogging*.—The particular manner of fixing the tie-beams to the wall-plates. One method is by dovetailing; the other is by notching the under side of the tie-beam, and cutting the wall-plate in the reverse form to fit it.

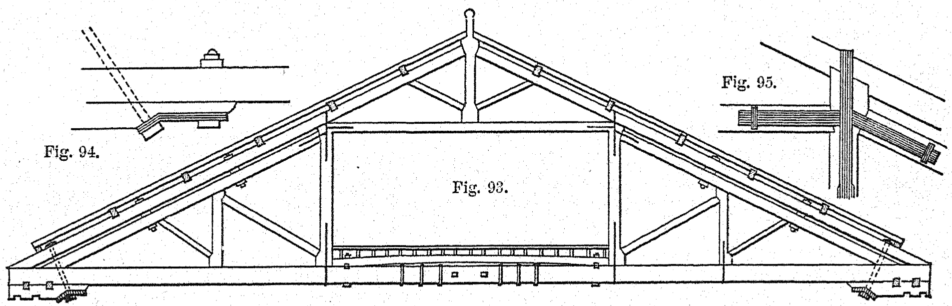


Fig. 94. Fig. 93. Fig. 95.

Ridge-tree.—A piece of timber fixed in the vertex of a roof, where the common rafters meet on each side of it. The upper edge of it is higher than the rafters, for the purpose of fixing the lead which goes over it to cover the ends of the slates in the upper course.

Straps.—Thin pieces of iron running across the junction of two or more parts of a truss or frame of carpentry, branching out from the intersection in the direction of the several pieces. They ought always to be double—viz., one on each side of the timbers, and their ends strongly bolted to each of the pieces.

The uses of these various parts will be illustrated in the subsequent examples; but it must be understood that though every one of them *may* be found in the same roof, it is not necessary that any complete roof should have them all. The introduction of many of them depends on the distance of the walls, the contour of the roof, the partitions below, the quantity of head-room wanted in the garrets, etc.

The three annexed illustrations, from three excellent English examples, are here given as affording not only sound instruction in the principles of construction, but as good studies for drawing.

Fig. 91 is the truss employed in the roof of the chapel of the Royal Hospital at Greenwich, already alluded to.

It is constructed with two queen-posts, B B, and has two struts, C C, from the foot of the queen-posts to the straining-beam, D, and which abut against a second straining-piece, E, underneath the first. The tie-beam, A, is also further suspended from the straining-beam by an iron rod, H, which answers the purpose of a king-post.

The following are the scantlings of the various timbers, which are given to enable the student to work this example to a regular scale, and which should not be smaller than a quarter of an inch to the foot.

	Inches scantling.
A. The tie-beam, 57 feet long, the span of the walls being 51 feet	14 × 12
B. Queen-posts	9 × 12
C. Braces	9 × 7
D. Straining-beam	10 × 7
E. Straining-piece	6 × 7
F. Principal rafters	10 × 7
G. Camber-beam for platform	9 × 7
H. Iron rod supporting tie-beam	2 × 2

The trusses are seven feet clear apart. The platform is covered with lead, which is supported by horizontal beams 6 × 4 inches. The timbers of this are well disposed, and contain, perhaps, less wood than most roofs of the same dimensions.

Of course, the tie-beam must be drawn first, then the queen-posts, the principal rafters, and straining-beam; next, the struts and straining-piece; then follow the iron rod, the camber-beam, the purlins, and the covering.

Fig. 92 is the roof of St. Paul's, Covent Garden, London, designed by Mr. Hardwick and constructed by Mr. Wapshot in 1796.

This roof, although of the same general construction as the last, varies from it in several particulars.

There is a second pair of principals, H H, which are supported on the lower, F F, by studs, and the lower principals thus become only auxiliaries. The queen-posts, B B, are continued up to the principals, and a king-post, D, is carried from the apex to the straining-beam.

The following scantlings are given for the same reason as in the last case:—

	Inches scantling.
A. The tie-beam, spanning 50 feet 2 inches	16 × 12
B. Queen-posts	9 × 8
C. Straining-beam	10 × 8
D. King-post (14 inches at the joggle)	9 × 8
E. Struts	9 × 8
F. Auxiliary rafters at bottom	10 × $8\frac{1}{2}$
H. Principal rafters at bottom	10 × $8\frac{1}{2}$
I. Studs supporting the principals	8 × 8

It will be seen that this roof consists of an outer truss supported by an under one, the whole projecting seven feet beyond the walls.

Fig. 93 represents the present roof of Drury Lane Theatre, London. Here are both principal and auxiliary rafters, the tie-beam being suspended at two points from the former, and two from the latter, the two first queen-posts being the inner ones. These are kept apart by the straining-beam, against which they are pressed from the outer side by the auxiliary rafters. Struts are placed between the feet of the principal and the heads of the secondary queen-posts, and the bearing of the sub-rafters is still further reduced by a strut from the foot, and on the other side of the smaller queen-posts. The straining-beam is supported by a king-post, from the apex of the principals, which, in their turn, are supported by struts from the foot of the king-post, the other portion having a continuous bearing on the auxiliary rafters.

Fig. 94 shows how the timbers are joined and strapped at the top of the queen-posts, the whole being tightened up by iron wedges at the lower end of the iron strap.

Fig. 95 shows how the ends of the tie-beams are strengthened by saddle-pieces, and how the principal and auxiliary rafters are inserted and bolted on to them. It will be observed that the heads of both the bolts pass through the same iron plate, which is bent at the oblique part of the saddle-piece, so that the head of the bolt may be at right angles to its length.

The method of drawing both the last figures is so precisely similar to the previous example, that no further instructions are deemed necessary.

THE STEAM ENGINE.—VI.

By Archibald Sharp, B.Sc., Wh.Sc., A.M.I.C.E.,
Instructor in Engineering Design at the Central Institution of the City and Guilds of London Institute.

[*Continued from p.* 293.]

WORK DONE DURING EXPANSION.

We have already seen that if a diagram be drawn, having the volume of an expanding fluid as abscissæ and the corresponding pressures as ordinates, the area of the diagram represents the external work done during expansion. If the fluid be compressed, the area of the volume-pressure diagram will evidently represent the work done by some external agency in compressing the fluid. Therefore, if a fluid work in a cycle, *a b c d a* (Fig. 42), during the expansion *a b c* the work done by the fluid is equal to the area *a′ a b c′ c*, and during the compression, or back-stroke, the work done on the fluid is equal to the area *c′ c d a a′*. Consequently the net work done by the fluid during one cycle is the area of the closed curve *a b c d*. In this case the direction of the path of the fluid is indicated by the arrows; if the arrows were reversed, *i.e.*, if the path of the fluid were *a d c b a*, during one cycle the work done *on* the fluid would be represented by the area of the closed curve.

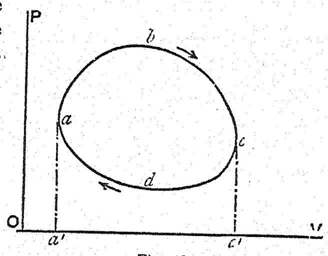


Fig. 42

In the cycle *a b c d e f a* (Fig. 43), the net work done during one cycle is the difference of the areas of the two closed curves *a b c f*—the arrows along the curve indicating rotation in watch-hand direction—and *c d e*; the arrows here being in contrary-watch-hand direction.

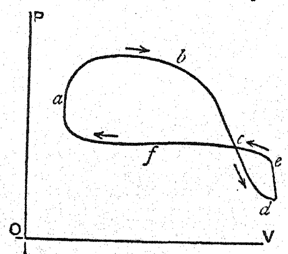


Fig. 43.

Hyperbolic Expansion.—It will be instructive to work the following example:—A steam-engine has a cylinder 1 square foot in sectional area, the stroke of the piston is 2 feet, the steam is admitted at a pressure of 80 lb. per square inch absolute, and cut off at $\frac{1}{4}$ stroke. Find the work done per stroke.

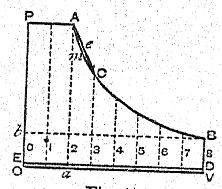


Fig. 44.

We will first calculate the steam-pressure in the cylinder at different parts of the stroke of the piston. In Fig. 44, O V = stroke of piston = 24″. Divide this up into a number of equal parts, say 8, and erect ordinates to represent the steam-pressure. At ordinates 0, 1, and 2, p = 80 lb. per square inch. At A the expansion curve begins, its equation being $p\,v$ = constant.

At ordinate 2, $v = 6, p = 80 \therefore pv = 480.$
,, 3, $v = 9, pv = 480, \therefore p = \frac{480}{9} = 53{\cdot}33.$
,, 4, $v = 12$, ,, ,, $\therefore p = \frac{480}{12} = 40{\cdot}0.$
,, 5, $v = 15$, ,, ,, $\therefore p = \frac{480}{15} = 32{\cdot}0.$
,, 6, $v = 18$, ,, ,, $\therefore p = \frac{480}{18} = 26{\cdot}66.$

At ordinate 7, $v = 21$, $pv = 480$. $\therefore p = \frac{480}{21} = 22{\cdot}86$.

" 8, $v = 24$, " " $\therefore p = \frac{480}{24} = 20{\cdot}00$.

We now can find the work done in any part of the stroke included between two consecutive ordinates. For example: in the part of stroke 2–3, if we consider the expansion curve A C to be a straight line the mean pressure during the period is $\frac{80 + 53{\cdot}33}{2} = 66{\cdot}66$ lb. per square inch.

Similarly—

During period 3 – 4, mean pressure is $\frac{53{\cdot}33 + 40{\cdot}0}{2} = 46{\cdot}66$.

" " 4 – 5, " $\frac{40{\cdot}0 + 32{\cdot}0}{2} = 36{\cdot}0$.

" " 5 – 6, " $\frac{32{\cdot}0 + 26{\cdot}66}{2} = 29{\cdot}33$.

" " 6 – 7, " $\frac{26{\cdot}66 + 22{\cdot}86}{2} = 24{\cdot}76$.

" " 7 – 8, " $\frac{22{\cdot}86 + 20{\cdot}0}{2} = 21{\cdot}43$.

The volume swept through by the piston in each period is $144 \times 3 = 432$ cubic inches; therefore—

In period 0 – 1, the work done is $432 \times 80 = 34{,}560$ in.-lb.
" 1 – 2, " " $\times 80 = 34{,}560$ "
" 2 – 3, " " $\times 66{\cdot}66 = 28{,}798$ "
" 3 – 4, " " $\times 46{\cdot}66 = 20{,}157$ "
" 4 – 5, " " $\times 36{\cdot}0 = 15{,}552$ "
" 5 – 6, " " $\times 29{\cdot}33 = 12{,}670$ "
" 6 – 7, " " $\times 24{\cdot}76 = 10{,}696$ "
" 7 – 8, " " $\times 21{\cdot}43 = 9{,}257$ "
$\therefore$ Work done per stroke $= 166250$ "
or 13,854 foot-pounds.

The arithmetical work may be conveniently tabulated as follows:—

Ordinate.	Pressure.	Mean Pressure during Period.	Work Done during Period.
	lb. per sq. in.	lb. per sq. in.	inch-pounds.
0	80		
1	80	80·0	34,560
2	80	80·0	34,560
3	53·33	66·66	28,798
4	40·00	46·66	20,157
5	32·00	36·00	15,552
6	26·66	29·33	12,670
7	22·86	24·76	10,696
8	20·00	21·43	9,257
		Total	16,6250

The work might have been more expeditiously performed as follows:—The mean pressure during the stroke is the mean of the mean pressures in the third column of the above table; if these numbers are added together and divided by eight, the result is the required mean pressure during the stroke. But the third column need not even be calculated, for on referring to the detailed calculation above it will be seen that the sum of the numbers in the third column is

$$\frac{80 + 80}{2} + \frac{80 + 80}{2} + \frac{80 + 53{\cdot}33}{2} + \frac{53{\cdot}33 + 40{\cdot}0}{2} + \frac{26{\cdot}66 + 22{\cdot}86}{2} + \frac{22{\cdot}86 + 20{\cdot}00}{2}$$

$$= \frac{80}{2} + 80 + 80 + 53{\cdot}33 + \ldots + 22{\cdot}86 + \frac{20{\cdot}0}{2}$$

We have, therefore, the following rule for getting the mean pressure during the stroke:—Add half of the first and last ordinates to the sum of the other ordinates, and divide by the number of equal parts into which the stroke is divided. This is known as "Simpson's Rule."

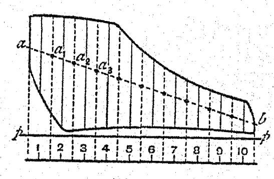


Fig. 45.

In our example the mean pressure is, therefore, 48·11 lb. per square inch.

The total pressure on the piston is $48{\cdot}11 \times 144 = 6{,}928$ lb.

The work done per stroke $= 6{,}928 \times 2 = 13{,}856$ foot-pounds.

Let p_1 = initial pressure = O P (Fig. 44).
" v_1 = volume at cut-off = O a.
" v_2 = " " end of stroke.
" r = ratio of expansion $= \frac{v_2}{v_1}$.

Then for *hyperbolic expansion* the area a A B V (Fig. 44) is equal to $p_1 v_1 \log_e r$.*

The area O P A $a = p_1 v_1$.

Therefore area O P A B V $= p_1 v_1 (1 + \log_e r)$, $\log_e r$ being the "hyperbolic" logarithm, or the "natural" or "Napierian" logarithm of r. A short table of natural logarithms is given, Table III.

Adiabatic Expansion.—Let the curve A C B (Fig 44) be of the form $p\, v^n$ = constant.

In this case the area a A B V is

$$= \frac{p_1 v_1 - p_2 v_2}{n - 1}.$$

This can be calculated as follows:—On page 152 we proved that the area P A B b (Fig. 44) is $= n$ times area a A B V. But it is also equal to a A B V + O P A a – O b B V.

$$\therefore n \times a\text{ABV} = a\text{ABV} + p_1 v_1 - p_2 v_2;$$

$$\text{or} \quad a\text{ABV} = \frac{p_1 v_1 - p_2 v_2}{n - 1}.$$

Applying the general exact formula to the example given and already worked out in detail

* This can be proved as follows:—

$$\text{The area } a\text{ABV} = \int_{v_1}^{v_2} p\,dv = c \int_{v_1}^{v_2} \frac{dv}{v}$$

$$= c(\log_e v_2 - \log_e v_1) = c \log_e \frac{v_2}{v_1} = p_1 v_1 \log_e r.$$

TABLE III.

HYPERBOLIC LOGARITHMS.

	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
1.	0	·0953	·1823	·2624	·3365	·4055	·4700	·5306	·5878	·6419
2.	·6931	·7419	·7885	·8329	·8755	·9163	·9555	·9933	1·0296	1·0647
3.	1·0986	1·1314	1·1632	1·1939	1·2238	1·2528	1·2809	1·3083	1·3350	1·3610
4.	1·3863	1·4110	1·4351	1·4586	1·4816	1·5041	1·5261	1·5476	1·5686	1·5892
5.	1·6094	1·6292	1·6487	1·6677	1·6864	1·7047	1·7228	1·7405	1·7579	1·7750
6.	1·7918	1·8083	1·8245	1·8405	1·8563	1·8718	1·8871	1·9021	1·9169	1·9315
7.	1·9459	1·9601	1·9741	1·9879	2·0015	2·0149	2·0281	2·0412	2·0541	2·0669
8.	2·0794	2·0919	2·1041	2·1163	2·1282	2·1401	2·1518	2·1633	2·1748	2·1861
9.	2·1972	2·2083	2·2192	2·2300	2·2407	2·2513	2·2617	2·2721	2·2824	2·2925

The hyperbolic logarithm of a number is equal to its common logarithm multiplied by 2·3026.

The hyperbolic logarithm of ten times any number is equal to the hyperbolic logarith of the number + 2·3026. For example: from the table log_e 4·8 = 1·5686; log_e 48 = 1·5686 + 2·3026 = 3·8712; log_e 480 = 3·8712 + 2·3026 = 6·1738.

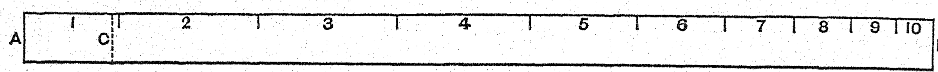


Fig. 46.

we have $p_1 = 80$, $v_1 = 144 \times 6 = 864$ cubic inches, $\log_e 4 = 1·3863$.

∴ Work done per stroke = 80 × 864 × 2·3863
= 164940 inch-pounds = 13745 foot-pounds.

This is less than the approximate value first calculated, the difference representing the areas of parts—like A e C m—included by the curve and its chord between the extremities of two consecutive ordinates. In this example the error is less than 1 per cent.

Back Pressure.—During the backward stroke of the piston, work is done in forcing the piston against the "back" pressure in the cylinder. In a condensing engine the back pressure would be from 3 to 5 lb. per square inch. In the example given, suppose a back pressure of 4 lb. per square inch, the work to be deducted per stroke is

4 × 144 × 2 = 1152 foot-pounds.

The back-pressure line D E is shown in Fig. 44, The cycle or "indicator diagram" is P A C B D E P.

The net work per stroke = 13745 − 1152
= 12593 foot-pounds.

Clearance.—In the above calculation, when the piston is at the beginning of its stroke, the space between it and the cylinder has been assumed zero. In practice there is always a considerable amount of space, called clearance, which has of course to be filled with steam at each stroke. The effect of this clearance space is to make the real and nominal ratios of expansion different. In the example given above, if the clearance volume were $\frac{1}{8}$th of the volume swept through by the piston during each stroke (calling v this volume), the volume of steam at the beginning of expansion would be $\frac{1}{4}v + \frac{1}{8}v = \frac{3}{8}v$, and the volume of steam at the end of the stroke $v + \frac{1}{8}v = \frac{9}{8}v$. The real ratio of expansion would therefore be $\frac{\frac{9}{8}v}{\frac{3}{8}v} = 3$.

When the work of an engine has to be estimated from an "indicator diagram" the procedure is as

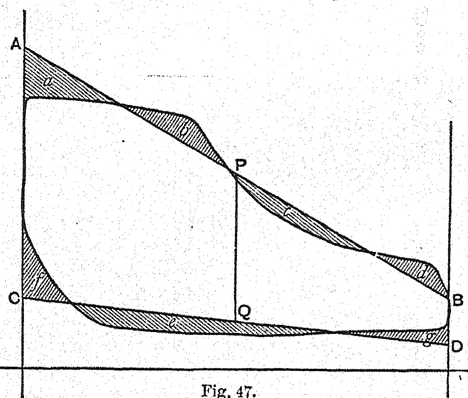
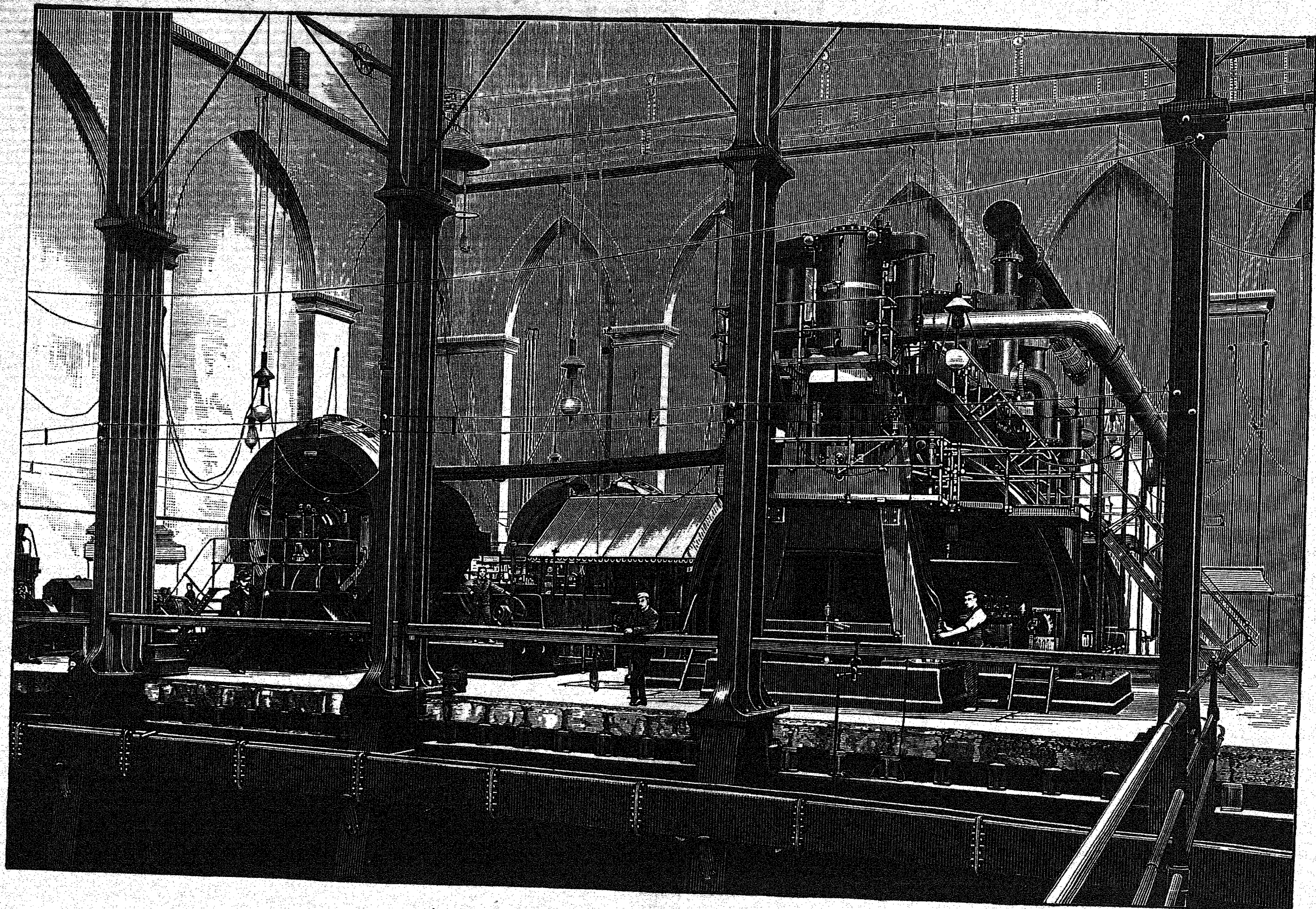


Fig. 47.

follows:—Draw the two end ordinates at right angles to the atmospheric line $p\,p$ (Fig. 45), and divide the abscissa into ten equal parts, and at each division draw an ordinate (dotted lines, Fig. 45). This division can be most easily done thus:—Take a fully-divided drawing-scale and set its edge to the diagram so that the length $a\,b$ (Fig. 45), intercepted between the end ordinates, is a multiple of ten divisions. The points a_1, a_2, a_3, etc., at a distance apart equal to one-tenth $a\,b$, are marked off



A CENTRAL ELECTRIC SUPPLY STATION.
[DEPTFORD STATION OF THE LONDON ELECTRIC SUPPLY CORPORATION.]

with a needle or the drawing-pencil, and ordinates drawn through them. (A scale of inches subdivided into fiftieths—*see* Drawing for Engineers—will be most suitable.) The lengths of the middle ordinates (full lines, Fig. 45) are marked off in succession on the edge of a strip of section-paper (Fig 46). The

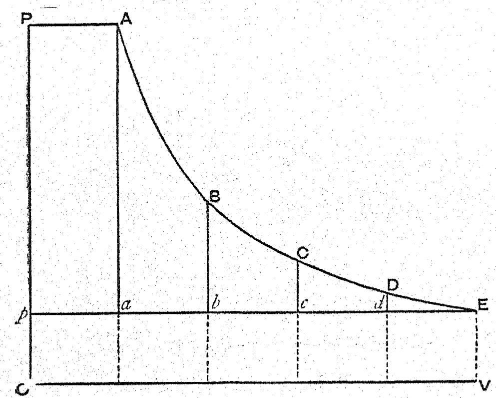


Fig. 48.

total length A B of this strip divided by 10 gives the "mean effective pressure" during the stroke to the same scale as the scale of pressures in the diagram.

During an engine-trial the mean pressure is sometimes required as quickly as possible. The following gives a good approximation :—Draw the end and middle ordinates of the diagram (Fig. 47). Draw the straight line A B so that, as accurately as can be judged by the eye, the area $a =$ area b, and area $c =$ area d. Draw the straight line C D so that the area e is equal to the areas f and g. The intercept P Q of the middle ordinate between A B and C D is the mean effective pressure required.

Horse-power.—Let $p =$ mean effective pressure in pounds per square inch ; a the piston area in square inches; s the stroke of the piston in feet; and n the number of revolutions per minute made by the crank-shaft.

Total pressure on piston $= pa$ lb.

Work done per stroke $= spa$ foot-pound.

" " revolution $= 2\,spa$ "

" " minute $= 2\,span$ "

$$\text{Horse-power} = \frac{2\,span}{33000}$$

For any particular engine s and a are constant, therefore

$$\text{Horse-power} = np \times \text{constant.}$$

This engine constant $= \dfrac{2\,as}{33000}$, and should be calculated for each engine. The horse-power as estimated above is called the "indicated horse-power" of the engine. "Brake horse-power" is the power actually transmitted from the engine, and is less than the indicated horse-power. The difference is spent in overcoming the internal frictional resistances of the engine.

Advantage of using steam expansively.—The student who has carefully read the foregoing lesson will see that to use steam economically it should be cut off early in the stroke of the piston. To fix the ideas better, consider the work done by a cubic inch of steam at 100 lb. pressure, the back pressure in the cylinder being 20 lb. If the steam be admitted during the whole piston stroke, the indicator diagram will be of the form p P A a (Fig. 48), and the work done per cubic inch of steam is $pv = 100 \times 1 = 100$ inch-pounds. From this must be deducted the work done against the back pressure during the return stroke of the piston, viz., $20 \times 1 = 20$ inch-pounds. If now the steam be cut off at half-stroke, the diagram takes the form p P A B b, and the work done per cubic inch of boiler-steam is proportional to this area. Similarly, if the cut-off takes place at $\frac{1}{3}$-stroke, the work done by each cubic inch of boiler-steam is proportional

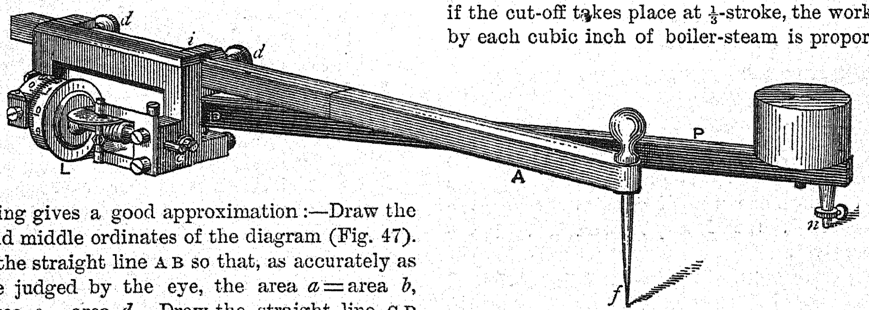


Fig. 49.

to the area p P A B C c. The numerical results are as follows :—

Ratio of xpansion	Work done per cubic inch of boiler-steam.
1	80 inch-pounds.
2	129·3 "
3	149·9 "
4	158·6 "
5	160·9 "
6	159·2 "

In this example an expansion of five times brings the steam pressure equal to the back pressure, and no advantage is gained by having a higher ratio of

expansion. With a lower back pressure the ratio of expansion might with advantage be higher. There are other factors, however, to be taken into account when determining the best ratio of expansion. These will be considered later on.

Planimeter.—The area of the indicator diagram can be quickly estimated by a planimeter. Fig. 49 shows a polar planimeter by Coradi, of Zürich. It consists of two arms, P and A, jointed together at the axis D. A needle-point, *n*, on the end of the arm P is pressed into the paper at any convenient place. On the arm A is mounted a graduated wheel, L, which rolls on the paper while the tracing-point *f* at the end of the arm A moves once round the closed curve. The number registered by the wheel L is proportional to the area of the closed curve. The length of the arm A between D and *f* is adjustable, and if this length be made equal to the length of the indicator diagram—as can easily be done in a planimeter intended to be used for indicator diagrams—the wheel L registers a number proportional to the "mean pressure."

DYEING OF TEXTILE FABRICS.—VI.

By J. J. Hummel, F.C.S.,

Professor and Director of the Dyeing Department of the Yorkshire College, Leeds.

[*Continued from p.* 305.]

OPERATIONS PRELIMINARY TO DYEING.

COTTON BLEACHING.

57. *Bleaching of Cotton Cloth or Calico.*—The mode of bleaching is varied according to the immediate object for which the bleached calico is intended; thus, one may distinguish between the *Madder-bleach*, the *Turkey-red-bleach*, and the *Market-bleach.*

MADDER-BLEACH.—This, the most thorough kind of calico-bleaching, was originally so-called because it was found specially requisite for those goods which had to be printed and subsequently dyed with madder.

Stamping and Stitching.—For the purpose of subsequent recognition, the ends of each piece are marked with letters and figures, by stamping them with gas-tar or aniline black. The pieces are then stitched together, end to end, by machinery.

Singeing.—This operation consists in burning off the nap or loose fibres which project from the surface of the cloth, since these interfere with the production of fine impressions during the printing process. It is performed by rapidly passing the cloth in the open width over red-hot plates or cylinders, or over a row of gas flames.

Fig. 19 shows a usual arrangement of the plate-singeing machine. By means of the rollers R, driven by a small engine, the piece G is rapidly drawn across the two red-hot copper plates P P,

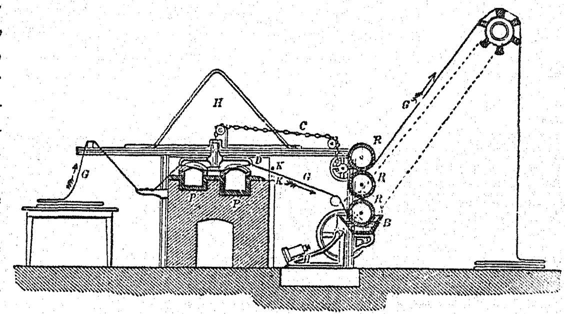


Fig. 19.—PLATE-SINGEING MACHINE.

against which it is depressed by the four bars of the iron frame D, capable of being raised or lowered by the chain C. Immediately on leaving the plates the piece passes between two perforated steam pipes K K, and through the water trough B, so that all adhering sparks may be at once extinguished: H is a hood for leading away the products of combustion. The two plates are heated by means of the furnace below.

The great difficulty in plate-singeing is to keep the plates at a uniform strong red heat, owing to the rapid cooling action of the passing pieces; hence the "revolving singeing roller" is a decided improvement on the plate. In this arrangement the flames from the furnace pass through a copper cylinder which slowly revolves, so that a fresh red-hot surface is continually presented to the piece, and a regular even singe is thus obtained.

As a rule, hot-plate or cylinder singeing is preferred for thick heavy cloth, but for light thin cloth—*e.g.*, muslins, etc.—singeing by gas is generally adopted.

The gas singeing machine consists essentially of one or more rows of gas jets, over which the cloth is rapidly drawn. The gas is mixed with air just before being burnt, so that an extended line of the well-known smokeless Bunsen flame is presented across the full width of the piece. By means of levers the gas jets may be placed at any suitable distance from the cloth, or in case of accident they can be entirely withdrawn from it.

The preliminary work of stamping, stitching, and singeing is succeeded by the bleaching operations proper, which, for 24,000 kilos. cloth and with low pressure kiers, may be summarised as follows:—

1. Wash after singeing.
2. Lime-boil: 1,000 kilos. lime, boil 12 hours; wash.
3. Lime-sour: hydrochloric acid, 2° Tw. (Sp. Gr. 1·01); wash.
4. Ley-boils: 1st, 340 kilos. soda-ash, boil 3 hours.
   2nd, 860 kilos. soda-ash, 380 kilos. resin, 190 kilos. solid caustic soda, boil twelve hours.
   3rd, 380 kilos. soda-ash, boil 3 hours; wash.
5. Chemicking: bleaching powder solution, ¼°—½° Tw. (Sp. Gr. 1·00125—1·0025) wash.
6. White-sour: hydrochloric acid, 2° Tw. (Sp. Gr. 1·01), pile 1—3 hours.
7. Wash, squeeze, and dry.

(1) *Wash after Singeing.*—The object of this operation is to wet out the cloth and make it more absorbent, also to remove some of the weaver's dressing. The pieces are drawn direct from the adjacent singeing house, guided by means of white glazed earthenware rings ("pot-eyes"), through a washing machine; they are at once plaited or folded down on the floor and there allowed to lie "in pile" for some hours to soften. By this first operation, frequently called "grey-washing," the pieces, hitherto in the open width, assume the chain form, which they retain throughout the whole of the succeeding operations.

(2) *Lime-boil* ("Lime-bowk").— The pieces are now run through milk of lime, and drawn by overhead winches into the kiers, there to be plaited down and well packed by trampling under foot.

Two boys enter the kier, and by means of small sticks they direct the incoming cloth to any desired position.

Fig. 20 shows an ordinary low-pressure kier, A, partly in section. The pieces rest on the perforated false bottom C, being carefully packed around the central puffer-pipe B. Water being then run in, the lid D is screwed down and steam is admitted through the pipe H, the two-way valve K, and the pipe J, immediately beneath the puffer-pipe. As soon as the water below the false bottom begins to boil, a portion is ejected up the puffer-pipe and spread over the cloth by means of the bonnet M. It filters gradually through the cloth, soon to be ejected as before, and thus an intermittent circulation of the boiling lime-water is maintained. Other accessories of the kier shown are the steam-pressure gauge L, the liquor or water-pipe I, and the let-off valve G.

The essential action of boiling with lime is to decompose the fatty, resinous, and waxy impurities present in the fabric. They are not removed, but remain attached to the fibre in an altered form, as insoluble lime soaps, which can, however, be readily got rid of by the subsequent processes.

Care must always be taken that a sufficiency of water is present in the kier, otherwise the cloth, especially that at the top or the bottom, is liable to be tendered. Too much liquor is almost equally objectionable, since the pieces are then apt to become entangled and damaged by tremulous boiling.

Instead of the low-pressure kier, other forms of kier may be employed, chiefly with the view of obtaining better circulation and decreasing the time of

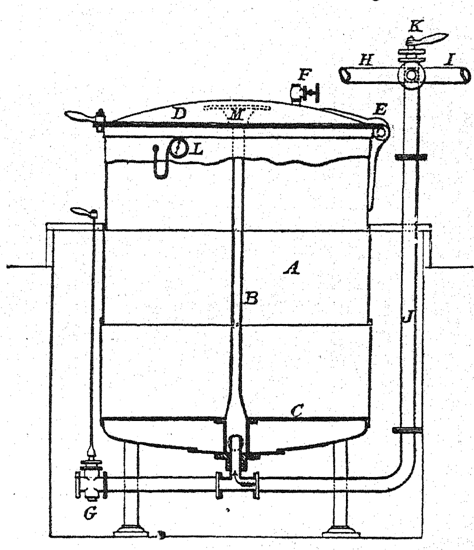


Fig. 20.

boiling. *Barlow's kiers* are worked in pairs, the bottom of one being connected with the top of the other. Both kiers are filled with cloth, and the boiling liquor is forced several times from one to the other alternately, issuing from central perforated pipes and thus through the cloth. *Pendlebury's kiers* are precisely similar in arrangement. In the *vacuum kier* of Mason and others the liquor is circulated by a pump, first pumping out the air from the kier filled with cloth, and then admitting the boiling liquor. In Mather & Platt's *injector kier*, the central pipe is absent, and the liquor is circulated by an external steam injector connected by pipes with the upper and lower parts of the kier.

(3) *Lime-sour.*—This operation, also called the "grey sour," consists in washing the pieces with dilute hydrochloric acid in a machine identical with the ordinary washing machine. The above-mentioned insoluble lime soaps are thus decomposed and the lime is removed; any other metallic oxides present are also dissolved out, and the brown colouring matter is loosened. Hydrochloric acid is preferred to sulphuric acid because it forms a more soluble compound with the lime. Care must be

taken to maintain the strength of the dilute acid as uniform as possible, both by having a regular flow of fresh acid from a stock cistern, and by making occasionally rapid acidimetrical tests. After souring, it is advisable not to leave the pieces long in their acid state, but to wash them as soon and as completely as possible, otherwise a tendering action may take place.

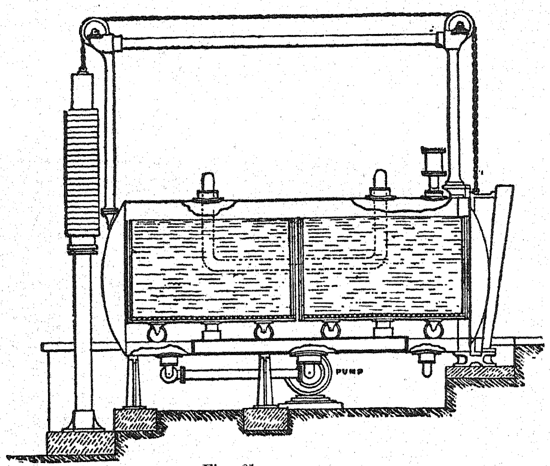


Fig. 21.

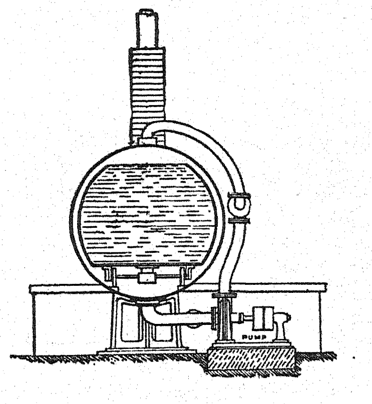


Fig. 22.

(4) *Ley- or Lye-boil.*—The object of this operation is to remove the fatty matters still remaining on the cloth. The fatty matters having been decomposed during the lime-boil, and the lime having been removed from the lime soaps by the souring, the fatty acids still remaining on the cloth are readily dissolved off by boiling with alkaline solutions. The brown colouring matters are also chiefly removed at this stage. The boiling takes place in exactly the same kind of kiers as those used for the lime-boil.

Some bleachers, as already indicated, boil with soda-ash alone, before the resin-boil, in order to neutralise any traces of acid accidentally left in the cloth from the souring. Another plan to avoid tendering is to let the goods steep or "sweeten" in a weak soda-ash solution for a short time, and then to draw it off again before commencing the boiling operation with "resin soap."

The boiling with resin soap is a very special feature in the madder-bleach. Experiment has shown that it removes certain matters which would subsequently attract colouring matter in the dye-bath.

The boiling with soda-ash solution after the "resin-boil" is useful, in order to ensure the complete removal of fatty matters and undissolved resin.

Since the cloth is very liable to contract iron stains if left in the kier too long after the alkaline liquor has been drained away, it is well to wash immediately after the ley-boils.

(5) *Chemicking.*—After all the previous operations the cloth retains a faint creamy tint, and the object of chemicking is to destroy the traces of colouring matter still present. The pieces are passed through a very dilute solution of chloride of lime or "bleaching-powder," in a "chemicking" machine, which is exactly similar to that employed for washing; they are then allowed, while still moist, to remain in pile and thus exposed to the air for several hours or over-night. The bleaching action, which must be considered as one of oxidation, takes place largely during this exposure, hypochlorous acid being then liberated by the action of the carbonic acid of the air.

It is essential that the bleaching-powder solution should not be too strong, otherwise the cloth may be tendered or be partially changed into oxycellulose, and thereby caused to attract certain colouring matters in the dye-bath, or to contract brown stains during subsequent processes, *e.g.*, steaming. For the same reason the solution of bleaching-powder must be entirely free from undissolved particles.

The bleaching power of the liquor should be maintained as constant as possible by having a continual flow of fresh bleaching-powder solution into the machine, and by occasionally testing how much of the liquor is required to decolourise a specially prepared standard solution of arsenite of soda, tinted with indigo extract or cochineal decoction.

(6) *White-sour.*—This operation does not differ from the lime-sour already described. Its object is

to complete the bleaching action by decomposing any "chloride of lime" still in the cloth, also to remove the lime, the oxidised colouring matter, and any traces of iron present. The cloth usually remains saturated with the acid a few hours.

(7) The *final washing* must be as thorough as possible. It is usually performed by the square beater machine, while the squeezing is done by Birch's machine, both of which will be illustrated subsequently. After squeezing, the cloth is again opened out to the full width, previous to drying. This is effected by allowing a good length of the cloth-chain to hang loosely and horizontally, and in this position to pass between a pair of rapidly revolving double-armed scutchers, which shake out the twists from the horizontal length of cloth. On leaving the scutchers, the piece which is now in the open width passes in a state of tension over one or more rollers provided with spiral projections, which tend to open out the cloth still more thoroughly; in this state it passes round the steam cylinders of the drying machine.

The average length of time required for the madder-bleach is four to five days.

The Steamer-kier Bleaching Process.—In 1885 Mather & Platt introduced the so-called steamer-kier represented in Figs. 21 and 22, whereby the duration of the bleaching process is shortened and the cost in labour, coal, and chemicals much reduced. It consists of a horizontal boiler into which two waggons, having perforated bottoms and filled with cloth, may be run on wheels. After closing the vertically sliding door of the kier, steam is admitted and the necessary liquor is sprinkled over the goods, being raised from an externally situated tank by means of a centrifugal pump connected with the top and bottom of the kier. During the boiling process an excellent circulation of the liquor is thus maintained. After boiling, the cloth may be washed in the kier itself by circulating boiling water. The kier is provided with two pairs of waggons, so that while the cloth in one pair is being boiled the other pair can be emptied and re-filled with cloth, and thus loss of time is avoided.

To effect a madder-bleach by the steamer-kier, the series of operations may be the same as those already described, but very good results are also obtained by the following curtailed process:—

1. Sour: pass through dilute H_2SO_4, 3° Tw. (Sp. Gr. 1·015°); pile 2—3 hours; wash and squeeze.
2. Ley-prepare: pass through following solution at 70° C.; 20 litres bisulphite of soda, 60° Tw. (Sp. Gr. 1·3); 20 kilos. NaOH (solid 72 per cent.), 1,800 litres water; pile in steamer waggons.
3. Ley-boil (or steam): Boil in steamer-kier 6—8 hours at 10 lb. pressure, with circulation of resin-soap liquor; 20 kilos. NaOH (solid 72 per cent.), 40 kilos. soda-ash, 20 kilos. resin, 2,000 litres water; wash 4 times (½ to 1 hour each time) with boiling water, and once with cold water, in kier.
4. Chemicking: pass through dilute bleaching powder solution, ½° Tw. (Sp. Gr. 1·0025); wash.
5. Sour: pass through dilute sulphuric acid, 2° Tw. (Sp. Gr. 1·01); wash and dry.

The object of the first souring is to decompose insoluble compounds of fatty acids, to remove calcareous and other mineral matter, and render soluble the starchy matter present. The addition of the bisulphite of soda to the ley-prepare is to prevent, by reason of its reducing power, any oxidation and tendering of the fibre during the steaming or boiling process.

TURKEY-RED-BLEACH.—When calico is intended to be dyed Turkey-red, certain modifications are introduced. It is found, for example, that singeing, and the application of bleaching-powder which causes the formation of oxycellulose, interfere with the production of the most brilliant colour. The apparatus employed being similar to that already described, it is only necessary to give the following summary of the operations usually carried out:—

1. Wash.
2. Boil in water for two hours and wash.
3. Ley-boils: 1st, 90 litres caustic soda, 70° Tw. (Sp. Gr. 1·35), boil ten hours and wash.
   2nd, 70 litres, ditto, ditto.
4. Sour: sulphuric acid, 2° Tw. (Sp. Gr. 1·01), steep two hours.
5. Wash well and dry.

The above quantities of materials are intended for 2,000 kilos. cloth, with low-pressure kier.

MARKET-BLEACH.—In market-bleaching the essential difference consists in the absence of the boiling with resin-soap, and the introduction of tinting the cloth with some blue colouring matter previous to drying. With many bleachers, the operation of chemicking comes between the two ley-boils, and not after them, as is usually the case.

DRAWING FOR ENGINEERS.—VI.

[*Continued from p.* 300.]

COLOURING DRAWINGS (*continued*).

THE three rules to be remembered in shading any surface may be enunciated as follows:—

1. The amount of light per unit area falling on a surface is roughly proportional to the cosine of the angle between the normal to the surface and the direction of the rays.

2. Of two surfaces receiving equal amounts of light that which is nearer *appears* the lighter.

3. Of two surfaces in shadow that which is nearer *appears* the darker.

Let us apply these rules to the shading of a vertical cylinder (Fig. 51). *c* is the centre of the circle forming the plan, *a b* a diameter parallel to X Y the ground-line, *c e* a radius at right angles to *a b*. Then *a e b* is the half of the surface visible in the elevation. Draw the radii *c d* and *c f* inclined

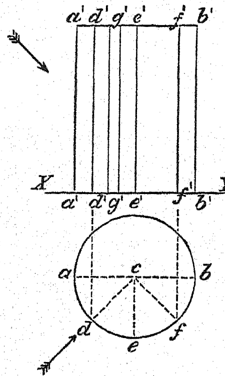


Fig. 51.

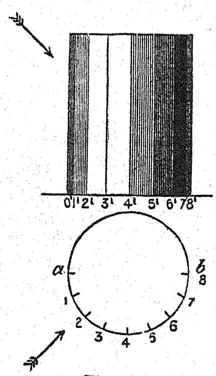


Fig. 52.

45° to *a b*. Then the surface to the right of *f* is in shadow, and in the elevation the darkest strip of shading will be just to the right of *f′f′*; the shading will be a little lighter towards the edge *b′b′*.

The light strikes the surface most directly at *d*, but *e* is the part nearest the spectator, so the lightest strip on the surface will be somewhere between *d′d′* and *e′e′*, say *g′ g′*. This part of the

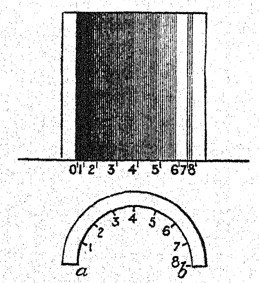


Fig. 53.

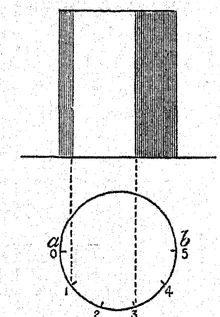


Fig. 54.

paper should be left white and the shading get gradually darker towards the right until the maximum shade at *f′f′* is reached. The shading on the left of *g′g′* should get gradually darker until the edge *a′ a′* is reached.

For working out an example take a cylinder 2″ diameter and 2½″ high. Divide the front semi-circumference *a b* (Fig. 52) into a number of equal parts, say 8, and project up the corresponding lines 1′ 2′ 3′ etc. on the elevation in very faint pencil lines. The darkest strip is between the lines 6′ and 7′; give a fairly dark wash of Indian ink to this strip. When dry, take a much lighter wash and cover the same strip and the adjoining strips on each side of it, that is, colour the space 5′ 8′; when dry, take a third and still lighter wash and colour space 4′ 8′. This completes the shading on the right of the lightest strip. The shading on the left side is done in the same way: 0′ 1′ gets a dark wash; when dry, a second light wash is given to the same strip and the adjoining one, *i.e.*, to the space 0′ 2′. The space 2′ 4′ may be left white.

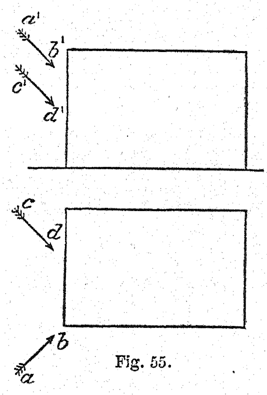


Fig. 55.

Care must be taken to choose the tints so that the change from the white paper at 2′ 4′ to the darkest strip at 6′ 7′ is gradually effected. Fig. 52 shows a cylinder shaded in this way. When the student has practised this example and can do it fairly well, he may take 12 or 16 divisions in the semi-circumference, and so get a more gradual change of shade.

Fig. 53 shows plan and elevation of a hollow half-cylinder, divided up into strips in the same way as in Fig. 52. Here the space 0′ 4′ is in shadow, and 0′ 1′, being the strip nearest the eye, will be the darkest. The light falls on the surface at 6′ most directly, but 8′ is nearer the eye. We may therefore make the strip 6′ 7′ the lightest. The line 4′ is the boundary of the shadow cast by the projecting left-hand portion of the cylinder. Except in highly finished drawings cast shadows need not be drawn, so the student in practising this exercise will vary the tint from the darkest at 0′ 1′ to white at 6′ 7′, and then a light tint on 7′ 8′.

On working drawings round parts may get a narrow strip of the body colour on one side and a broader strip on the other. Divide the semi-circumference *a b* (Fig. 54) into five equal parts, then the elevation may be coloured on spaces 0′ 1′ and 3′ 5′. This colouring suggests rather than imitates roundness.

Fig. 55 shows plan and elevation of a horizontal cylinder. In shading the plan, the light is assumed to come in the direction A B, represented in plan and elevation by *a b* and *a′ b′*. These lines are also the plan and elevation of one of the rays assumed to fall on the surface in shading the elevation. In the plan, then, the top and right-hand edges of a projecting part cast shadows; and if shade lines

are used, they must be put on top instead of bottom edges as shown in Fig. 25.

Some engineers prefer to shade the plan by rays in the direction C D (plan $c\,d$, elevation $c'\,d'$). Whichever of these two assumptions is made, the student must be careful to put in all shade-lines and shadows consistent with that assumption.

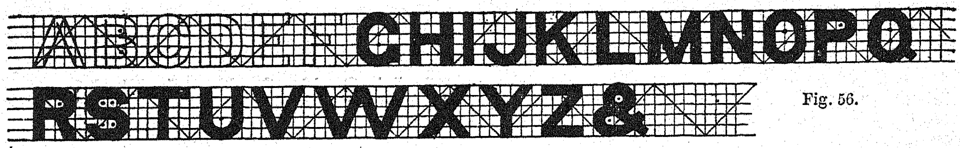


Fig. 56.

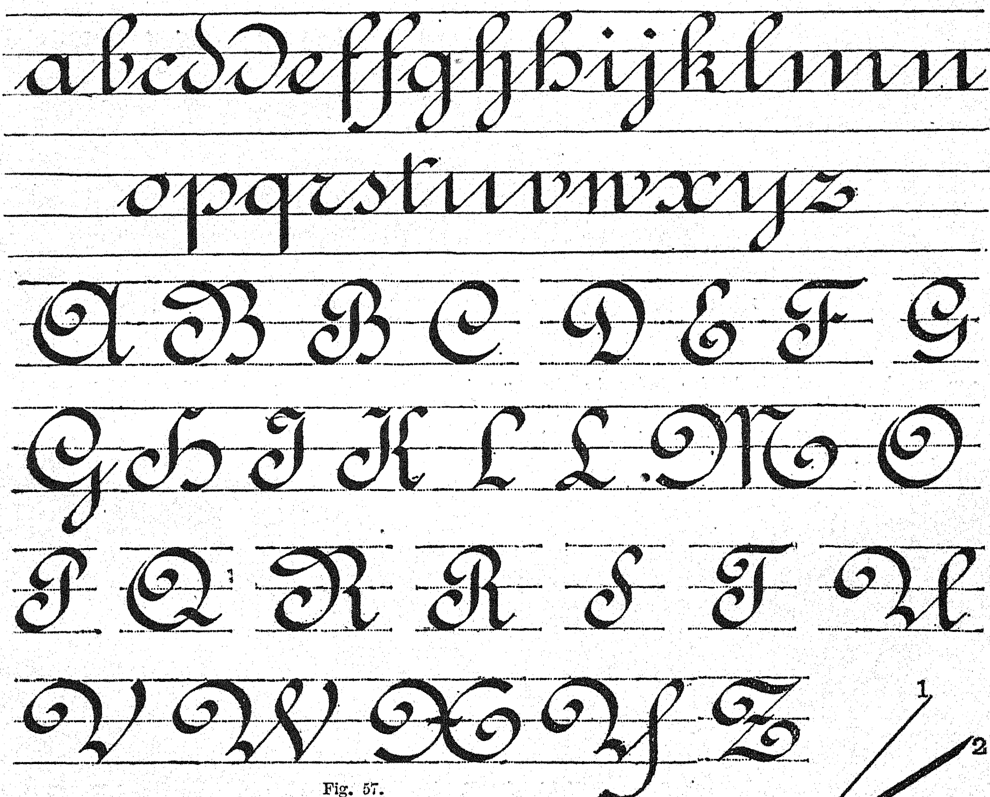


Fig. 57.

LETTERING AND FIGURING.

The title and scale of a drawing should be placed in a prominent part of the paper; block letters are, perhaps, the most suitable. Fig. 56 shows the alphabet in block letters. Block letters can be drawn mechanically as follows :—Having chosen the height of the letter to be used (which may be from $\frac{3}{8}'$ to $\frac{5}{8}''$, according to the size of the drawing-paper and the number of words in the title), divide it into five equal parts, and draw the six horizontal lines, as in Fig. 56, lightly with the pencil. Draw a series of equidistant vertical lines, so dividing up the space to be occupied by the letters into a number of equal squares. The spacing of these vertical lines can be most easily done by drawing a series of

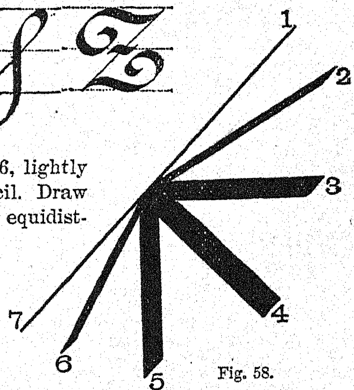


Fig. 58.

lines inclined 45°, as shown in Fig. 56; the intersections of these lines with the horizontals determine points through which the verticals are to be drawn. The curved parts of the letters are circular arcs (whose centres are indicated by the dots), and can be inked in at once by the spring bows; the straight parts can be ruled in by the drawing-pen, as shown in the first few letters. These lines should be inked in as thick as possible, so that the space between a pair of them can be filled in by rapid strokes of the brush without fear of overstepping the boundary. The pencil lines are rubbed out when the inking-in is finished. After a certain amount of practice, the student will be able to dispense with the mechanical helps, and will make the letters freehand with brush or pen. Indeed, well-formed freehand letters will look much better than those shown in Fig. 56.

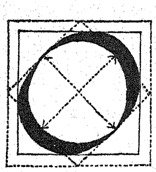


Fig. 59.

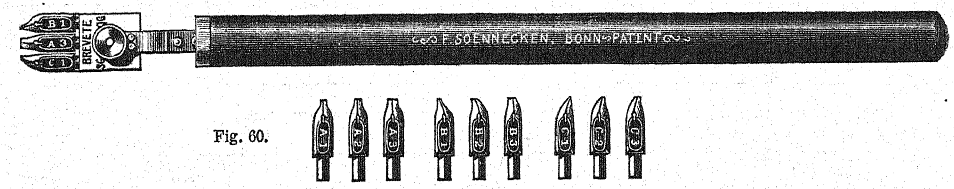


Fig. 60.

Fig. 61.

Fig. 57 shows the alphabet in "Round Writing," which is used extensively by continental draughtsmen, and which deserves to be better known in Britain. It is written with Soennecken's pens, which have very wide points. The pen is held so that its wide "point" (Figs. 58 and 62) makes an angle of 45° with the direction of the line to be written upon. As the pen moves over the paper its direction is kept invariable, so that, if moved from the position shown along lines 1 or 7, a thin line is produced; while if moved in any other direction a thicker line is produced, the thickness being greatest when the line drawn is at right angles to line 1 or 7. Fig. 59 shows the result got by moving the pen in a circle. The letters are all formed by combining straight lines and circular arcs. Fig. 62 shows some of the pens and the writing done by their use. The advantage of Round Writing is that it can be done very quickly after a little practice, and it looks very well on mechanical drawings. It is much easier to learn to do neatly than block or italic letters. Fig. 60 shows a "Writing Instrument" carrying three pens, and Fig. 61 is an example of the writing done by it.

A B C D E F G H I J K L
M N O P Q R S T U V W
X Y Z

a b c d e f g h i j k l m n
o p q r s t u v w x y z

Fig. 63.

Italic letters (Fig. 63) are also used for lettering mechanical drawings. The student is recommended to learn Round Writing first, then Block Lettering, and, lastly, Italic Lettering.

Figures used for marking dimensions should be as plain and distinct as possible. Fig. 64 may serve as a model for figures. When a dimension is

1 2 3 4 5 6 7 8 9 0

1″, $\frac{3}{4}$″ $2\frac{7}{8}$″, 1′. $9\frac{1}{2}$″.

Fig. 64.

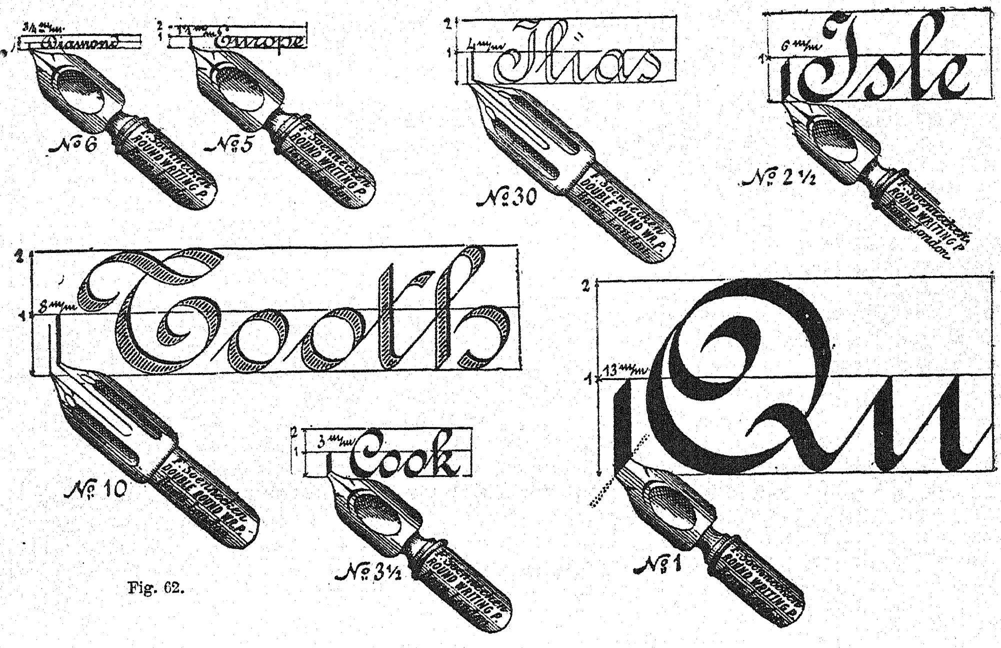


Fig. 62.

expressed in feet and inches, a considerable space ought to be left between the figures indicating the different units, or what was intended to read, say, 1′ 6″ may be read off 16″.

WOOLLEN AND WORSTED SPINNING.—VI.

By Walter S. B. McLaren, M.P.

[*Continued from p.* 313.]

WOOL WASHING AND OILING (*continued*).

44. *Test for Oil.*—The best oils are those which oxidise least, remain fluid longest, and saponify with the greatest facility with carbonate of soda without the addition of heat. The power of remaining fresh and unrancid is also of prime importance, and in this olive oil is pre-eminent. The following receipt is given for testing oil. Take a portion of oil and stir it up with forty parts of a solution of carbonate of soda of three degrees Baumé. If the oil forms a milky emulsion, without any oily drops on the surface, it is a guarantee for a good greasing of the wool.

45. *Quantity to be used.*—For worsted yarns the less oil that is used the better; three pints per pack (240 lb.) is quite enough for ordinary English wool. Very strong wool needs more, and absorbs it without showing that much has been used. For woollen yarns the following are very common quantities where the fibre is short and shoddy largely used. When the yarn is sold in the grease, for every 100 lb. of wool, 18 lb. of oleine and 30 lb. of water are mixed with it. Where the yarn is sold scoured, 12 per cent. of oleine and 30 per cent. of water are considered enough. The water should be hot and mixed with the oleine, a little sal ammoniac being used to help the assimilation. In making vigogne or angola yarns, which are mixtures of cotton and wool, the wool must be well mixed with the above proportions of oil and water before the cotton is put to it; otherwise the yarn will not be regular.

46. *Carbonisation.*—The subject of carbonisation may be dealt with here, as it comes under the description of washing. All wool before being salted contains much vegetable matter in the shape of seeds, grass, moss, burrs, and such things. Most of these can be taken out in the sorting, or fall out in the carding and combing, but some of them, especially burrs, cling so tenaciously to the fibre that they are carried through every process into the cloth. Among the worst classes of wool in this respect are Port Philip, Cape, and Buenos Ayres; they are often literally one mass of burrs. To pick them out by hand is impracticable, while if the wool is carded with them in, though some may be knocked out by burring rollers and other machines for the purpose, a great number are opened, and laid lengthways along the fibre, in form resembling

a small centipede, and in this state adhere more firmly than before to the wool. The only effectual method of removing them is by carbonisation. Sometimes this is done to the wool immediately after washing; at others it is done to the cloth before or after milling. The process is generally called carbonisation of wool or cloth, but it is not the wool which is carbonised, but the vegetable matter adhering to it. The effect is to reduce the vegetable fibre to cinders or dust, so that it will fall out when the material is washed or shaken.

47. *Methods employed.*—There are two methods most commonly employed for doing this. The one is to saturate the wool with dilute sulphuric acid of 4° to 5° Baumé, which is afterwards removed by "whizzing" the wool in a circular hydro-extractor. The wool is then spread out in a room heated to 250° Fahr., in order that it may dry quickly. The air being so hot absorbs the moisture very rapidly, leaving the acid in the wool. The acid, which has a strong affinity for water, lays hold of the burrs and other vegetable matters which still retain moisture, and extracts it from them, leaving only the cinders, which are little else but carbon, and which crumble away when the wool is afterwards washed. In extracting this moisture, however, the sulphuric acid is decomposed, and if any is left, it is so little as to do no harm to the fibre of the wool, especially as the wool is immediately washed. The other method is known as Joly's process, from the name of its inventor, a Frenchman. By it the wool is saturated with a solution of chloride of aluminium of 6° to 7° of strength Baumé, about 8 to 10 lb. of chloride being used to 16 lb. of wool. The wool is then whizzed in a hydro-extractor, and well dried in the ordinary way. After it is quite dry, it is taken to the carbonising room, which is heated to 212° Fahr., and left there for three-quarters of an hour. It is then washed with water and fuller's earth, by which all the chloride is removed, and the carbonised vegetable matter washed away. This method is the one generally adopted now, as it is simplest and safest for the wool, and at the same time attended with least inconvenience to the workmen.

Carbonisation can also be effected by the fumes of muriatic acid. The wool is placed on hurdles in an air-tight room, and exposed to its action for three or four hours, after which the temperature is raised to 212° or more. In a short time the heat is stopped, fresh air is let in, and the wool, when cool, is washed. The wool before being fumigated must be almost, but not quite, dry.

48. *Wool not Injured if Care be Taken.*—Before treating wool in any of these ways it is necessary to have it thoroughly washed, so as to remove every particle of grease. If this be not done, the result will be that the wool will be made tender, and cannot be milled, while it will not dye well. Experiments have been made to test this, and it has been found that "the sulphuric acid, acting on imperfectly cleansed wool, sets at liberty the fatty acids of the grease, which fix themselves on the wool, and cannot be got rid of by the ordinary processes." In addition to this, the grease that remains clogs the saw-like edges of the wool, gluing down the points of the serratures, thus making the edges smooth and unable to felt; and the fibres themselves are considerably weakened, so that on being milled they do not form a compact mass, but are liable to be torn or worked into holes. Where, however, the wool has been perfectly washed before being treated with the acids, no injury whatever is done to it; provided, of course, that the carbonising is effected properly, and that the whizzing in the hydro-extractor is sufficient. Wool washed in the usual way, and wool washed and carbonised, have been microscopically examined, and the scales and serrations of the latter have been found to be just as clear and perfect as those of the former. Strange to say, the strength of the fibre in the latter case is even increased. Herr Weisner, of Vienna, tested horse-hair and the hair of the Angora goat, and found that when the acid did not exceed 4 per cent., or the heat 60° to 65° C., fibres which previously had broken with a weight of 480 grs., now only broke with 568 grs. When the acid was raised to over 7 per cent. the fibre was weakened. Though wool will not bear an equally strong acid, yet if treated in proportion, its strength is not injured.

49. *Wiesner's Experiments.*—The following description of Herr Wiesner's experiments is worth reproducing here, as showing the different ways in which wool must be treated according to the character of the vegetable matter which it is desired to carbonise. After examining many kinds of wool, he found that the vegetable matter might be divided as follows:—1. Burrs of various kinds. 2. Fragments of straw and grass. 3. Raw textile fibres, such as jute. 4. Fragments of leaves, etc. 5. Dung, which was composed of pure woody or cuticular cellulose. Now there are three kinds of cellulose. It exists in a state of almost absolute purity in the bark and pith of the impurities in the wool, and in the dung. The solid cellular tissue in all vegetable matter consists principally of ligneous cellulose, and the cuticular cellulose is found in the rind of fruit, leaves, and stems.

"In his experiments," says the *Textile Manufacturer*, "Herr Wiesner employed for pure cellulose, Swedish filtering-paper; for ligneous cellulose, jute

and thin pine-wood shavings; and for cuticular cellulose, raw cotton. These substances were plunged into the sulphuric acid solution of given strength, left there for about a quarter of an hour at the temperature of the atmosphere, pressed carefully between sheets of filtering-paper, and then submitted to the action of a certain degree of heat. With an amount of acid equal to 1 or 2 per cent., and a temperature of 40° to 50° C., the ligneous fibres, at the end of three-quarters of an hour or an hour, became brittle, and brownish in colour, and at 55° they were carbonised. Pure cellulose presented rather more power of resistance; with 1 to 2 per cent. of acid it became brittle at the end of about an hour at 50° to 55°, it began to turn brown at 60°, and to blacken at about 65°; cotton did not become brittle till the heat was 60° to 62°, began to turn brown at 70° to 72°, and did not carbonise until the temperature reached several degrees higher. With a more concentrated solution, and greater heat, the decomposition of the three kinds was more rapid, but the differences remained the same between them. Before any signs of decomposition appeared the fibres all became so brittle that the slightest pressure reduced them to powder; it is therefore evidently unnecessary to burn or carbonise vegetable matter to purify wool from it. Vegetable substances, in carbonising, give out a smell of caramel, burnt sugar; the carbonised matter contains a brownish substance, soluble in water."

Thus it is seen that these vegetable substances can be removed from wool in an hour by employing 2 to 3 per cent. of sulphuric acid, and a temperature of 50° to 60° C. This is a matter which deserves much more attention from English manufacturers than it receives, especially in the worsted trade. Woollen manufacturers who make shoddy by extracting the wool from rags which have cotton in them are, of course, familiar with it. As is often the case, the warp may be cotton, and the weft worsted, or *vice versâ*, and the rags are then treated as above described, till only the wool is left. It is then worked up into shoddy, and mixed with more wool, to be again spun into yarn, and woven into cloth.

50. *Extraction of Oil from Soap-suds.*—A few words should be said regarding the extraction of oil from the refuse soap-suds, though this is not the place to describe all the chemical operations. The saving is so great, however, that no wool-washer ought to allow his suds to run away in the form they leave the bowls. Tanks are prepared to receive the suds, and when a tank is full, a certain quantity of vitriol is poured into it. This causes the sud to curd or crack, and the grease and all solid matter fall to the bottom, leaving the water comparatively clear. This water is then run off down the drain, and the thicker portion at the bottom is afterwards run into a filter-bed of sand and gravel, through which the rest of the water gradually filters, leaving the solid and greasy matter behind. This is laid in cloths and called "puddings," which are pressed in hydraulic or steam presses till all the oil is squeezed out. From what is left, potash and other ingredients can be extracted, and the refuse is used as manure. The oil must be purified, and can then be used with great advantage for soap-making or lubricating. As it is not worth while for each wool-washer to do this for himself, it is usual to sell the suds to extractors, whose business it is to carry out this operation. The price is, of course, clear gain to the washer, and the process has, at times, been very profitable also to the extractor, especially when much greasy colonial wool is used.

THE DIFFERENCE BETWEEN WORSTED AND WOOLLEN.

51. *Worsted and Woollen.*—Having now considered the processes employed in the sorting and washing of wool, it is well to understand what is the difference between the two sorts of yarn, worsted and woollen, into one of which it must be spun. Every spinner knows which class of yarn he spins, and most persons familiar with the trade could tell at once whether any given piece of yarn was worsted or woollen, but at the same time might find it difficult to say what characteristic it was which made yarn belong to the one class, and not to the other. Yet it is essential to know the difference between the two in order that the principle of the various operations in their manufacture may be properly understood.

52. *Former Distinction Untenable.*—It used always to be said that worsted was made of long wool which was combed, and woollen of short wool which was carded; the characteristic difference between these two processes being, that in the former the short wool is separated from the long, which alone is spun, while in the latter the short wool remains mixed among the long, and all the little lumps and knots are opened out by the action of the card-wires, so that the yarn may be comparatively smooth, and yet gain in bulky appearance owing to the short hairs in it. Formerly this was approximately correct, but it is no longer so; and the distinction, even if correct, would be entirely unscientific, because it leaves unanswered the question, Why must a worsted yarn be combed and a woollen one carded? what is the principle of the two processes which makes the difference in the result?

53. *Difference not in Length, nor in Combing and Carding.*—In the first place, the terms "long" and "short" are too vague, for, owing to the increased perfection of machinery, wool less than 2 inches long can be combed, while other wool of 6 or 8 inches is regularly carded, and even wool of much greater length can go through the cards with little injury. Botany wool of 2 inches long is made into merino cloth; while Cheviots and other similar wools of 5 or 6 inches long are made into rough woollen goods. It is clear, therefore, that the distinction between worsteds and woollens depending on the length of the fibre is no longer tenable. Nor is the distinction that one is combed and the other carded satisfactory. All woollen yarns are carded, or, to use another name, "scribbled"; but a large proportion of worsted yarns are carded also. There are three main classes of worsted yarns, which, however, to some extent overlap each other. The first is composed of long English and similar wool, which is combed after passing through what are known as "preparing boxes." Of the second class, yarn made of Botany wool may be considered representative, for the wool is short, and is first carded and then combed. Carpet yarns and coarse "fingering," or knitting yarns, compose the third class, and are made of wool of various lengths, which are carded without being combed afterwards, as the object in making them is to have them soft and bulky. These different classes cannot be kept distinct. A "top" of combed English wool may be mixed with one of carded and combed Botany to give it a finer quality; or the carpet yarn may have some combed wool to make it more level, and other combinations may be made. This shows that the idea that worsted yarn must be combed, and that all carded wool is spun into woollen yarn, is entirely erroneous, and a more accurate distinction must be found.

54. *Difference not in Mule and Throstle.*—By some persons it is supposed that this distinction lies in the spinning-frame—woollen yarn being spun upon the "mule," and worsted yarn upon the "throstle." The chief characteristic of the latter frame is that the yarn is twisted and wound upon a bobbin as fast as it is delivered by the pair of rollers which draw it out, and as this pair of rollers revolves constantly while the spinning frame is in motion, the principle of the throstle frame is known as "continuous drafting." The characteristic of the mule, on the other hand, is that the thread is drawn out by the rollers for about two yards before it is wound on to the bobbin, being kept stretched by means of the spindle and bobbin on which it is to be wound, travelling away from the rollers on a "carriage." In some cases, the rollers cease delivering when the carriage has gone about half its distance, and the yarn is then drafted by the carriage proceeding to the end of its journey and drawing out the roving which has been thus delivered. In other cases the rollers deliver as long as the carriage travels outwards; but in either way more twist, if necessary, can be put into the yarn by the spindle continuing to revolve after the rollers have ceased to deliver, and finally the yarn is wound on to the bobbin as the carriage which bears it again approaches the rollers. In consequence of this stoppage of the rollers, the drafting or drawing out of the yarn is not continuous. The former of these modes of mule spinning is most suitable for woollen yarn; while the principle of continuous drafting, and the latter mode of mule spinning, are most suitable for worsted. Woollen yarn has, until recently, been spun only on a mule since that machine was invented, but a spinning frame upon the throstle principle of continuous drafting has lately been made which is suitable for a sort of woollen yarn. Worsted certainly is spun upon the mule, the latter frame being chiefly in use on the Continent, and to a small extent now in this country, and it is found to be suitable for spinning combed as well as carded wool.

55. *Nor in Milling.*—As this distinction is untenable, we turn to another which is generally believed to be correct, namely, that woollen fabrics are milled or felted, while those of worsted are not. This is a still more unsatisfactory definition, because it deals with the cloth, whereas it is obvious that whatever difference there may be must exist in the yarn, seeing that both sorts of yarn can be woven in the same way. The definition also is not exhaustive, because some woollen cloths are only scoured and not milled, while some worsted ones (such as coatings) are slightly milled to give them greater firmness. There are also mixtures, of which the warp may be worsted and the weft woollen, and these may or may not be milled. As a rule, however, woollens are milled and worsteds are not, and it is indirectly in connection with this end that the solution of the problem is to be found.

56. *Difference lies in Arrangement of Fibres.*—The difference between worsted and woollen depends really on the arrangement of the fibres in the thread, and this indirectly depends on the fact that the fibres arranged in one way are less suited for felting than if they were arranged in another. This is not the place to describe the operation of milling or felting, further than to say that its object is to entangle and mat all the fibres of the cloth so thoroughly into one homogeneous whole, that each thread can no longer be distinguished, and the

cloth forms a solid and compact piece. Now, as most woollen cloths are intended for felting, it is necessary to prepare and spin the yarn in such a way as to facilitate the operation; and in consequence of the shrinking which takes place in the cloth owing to it, any slight imperfections, such as unevenness, are not easily seen.

57. *In Worsted, Fibres lie Smooth and Parallel.*—In worsted fabrics it is different. They are not as a rule intended to be felted, and therefore it is of the highest importance that the yarns of the better sorts should be level, smooth, and free from lumps of any kind, while even in the lower ones, such as carpet yarns, it is very desirable to have an even thread. To ensure this, and to have a smooth surface on the cloth, all the fibres of wool must be in the same direction in the yarn. That is the essential characteristic of a worsted thread. If the fibres are doubled up, crossed, or tumbled about in any way, it is impossible to have a really even thread. To insure this levelness, it is necessary in the finer yarns to remove, by means of combing, all the very short fibres and the knots and lumps which are inseparable from them. In the coarser sorts, such as carpet yarns, where this high degree of excellence is not needed, and where it is necessary to have a soft bulky yarn, it is not desirable to remove the short fibres by combing; but yet the wool is put through certain processes to ensure that, as far as possible, the fibres shall all lie in one direction.

58. *In Woollen, Fibres lie Roughly and Crossed.*—Compare this with a woollen thread. In it, instead of lying smoothly and having a regular twist to bind them together, the fibres are crossed and doubled in every direction. The thread is consequently rough and many loose fibres are seen to stand out from it. These are of great use in assisting the felting of the cloth, as they lay hold of each other and knit the different threads into one piece. The beauty of worsted is to have as few of these loose fibres as possible, and at the same time to have a round level thread, because the thread is seen in the woven fabric. On the other hand, as the woollen cloth is generally intended to be milled, the fibres must be arranged in such a way as to assist that operation; and it is found that when the fibres of wool lie in all possible directions in the thread, and when many of them stand out from the surface of it, their serrated edges are more exposed than when they lie smoothly stretched out in straight lines. In other words, by this rough arrangement of the fibres they get hold of each other better, and lap round each other more firmly in the felting; because as wool shrinks in the process, a fibre which is wrapped round several others will get a firmer grip of them than if it is stretched out lying by their side with very little twist in it.

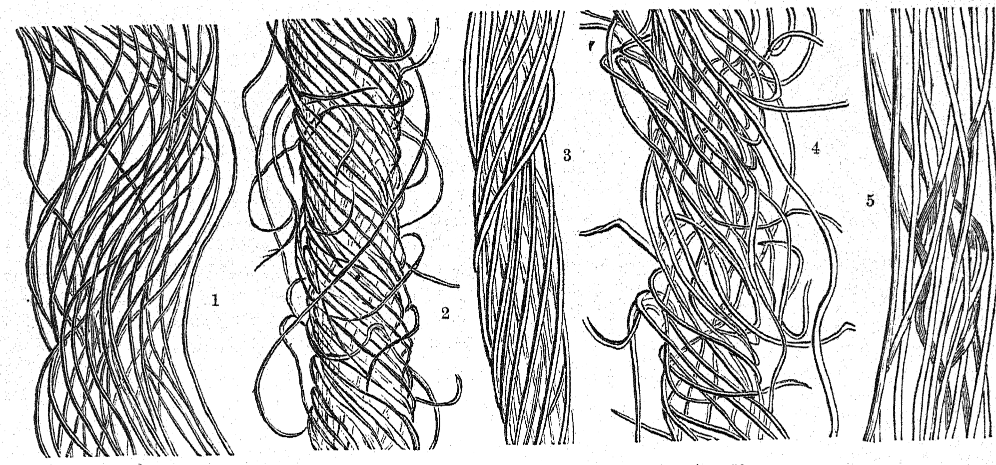


Fig. 10.—Woollen and Worsted Yarns (Threads) ×. 50.
1, 30's worsted made of fine wool; 2, 30-skein woollen made of fine wool; 3, 30's worsted made of strong wool; 4, 28-skein woollen made of Cheviot wool; 5, 30's lustre-worsted.

59. *Appearance of the two Yarns.*—The accompanying wood-cut (Fig. 10) shows more plainly than any description could do the difference in the construction of the two classes of yarn. Nos. 1, 3, and 5 are worsted; the first, being made of short fine wool, cannot lie so smoothly as the other two, because when the fibre is short, the waving, curly

nature of the wool asserts itself, for there is not sufficient resistance in the short length to keep it straight. In Nos. 3 and 5, however, the wool is long, perhaps twelve inches or more, and therefore it lies straighter; for if the tendency to curl be strongest in the middle of any given fibre, it is clear that if it be twelve inches long the resistance of six inches at each end, which are stretched out and twisted round other fibres, has to be overcome before the curl can commence. It is simply a question of the strength of the tendency to curl contending against the friction which the fibres exert on each other after they have been stretched out side by side. In long wool the friction is the stronger force and the fibres lie straight. In short wool the tendency to curl is stronger, and the reverse is the case. This is the chief reason why short rather than long wool is suitable for woollen yarn. This will further be seen from Nos. 2 and 4, in which no attempt has been made to straighten the fibres, but every chance has been given to them to take advantage of their natural characteristics, and they are so arranged as to be able to felt with each other with the greatest facility.

CARPENTRY AND JOINERY.—VI.

By B. A. Baxter.

[*Continued from p. 309.*]

ROOFS.

Roofs, as far as concerns the carpenter, are frames of wood, or wood and iron, to carry the tiles or slates which form the outer covering.

Properly arranged, the roof adds greatly to the stability of the building. If, however, the roof is badly designed and exerts an outward thrust on the walls, the covering that should protect the whole building from the weather may become an active agent in its destruction.

The simplest form of roof is, no doubt, the flat—merely a suitable floor, nearly level, for the sheet-metal worker to cover with zinc or lead; such a roof needs no description other than that given for flooring. The only necessary instruction, which can be had of the metal worker, consists in making such arrangement as shall enable the plumber to

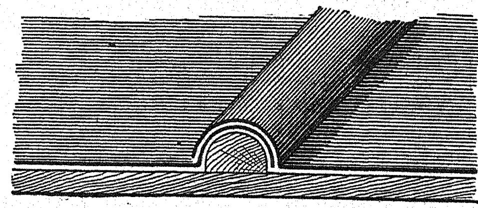


Fig. 71.—Lead Roofing.

lay his metal so that, though secure, it shall be free to expand or contract with changes of temperature. As the sheets of metal are usually turned up at the sides, a piece of wood is provided and fixed between each sheet, so that a piece of metal can cover both the wood and the edges of the metal on each side of the strip of wood (Figs. 71, 72). For exact dimensions and mode of fixing, the sizes of the metal, and the position of the gutters and mode of covering, and the material must be known.

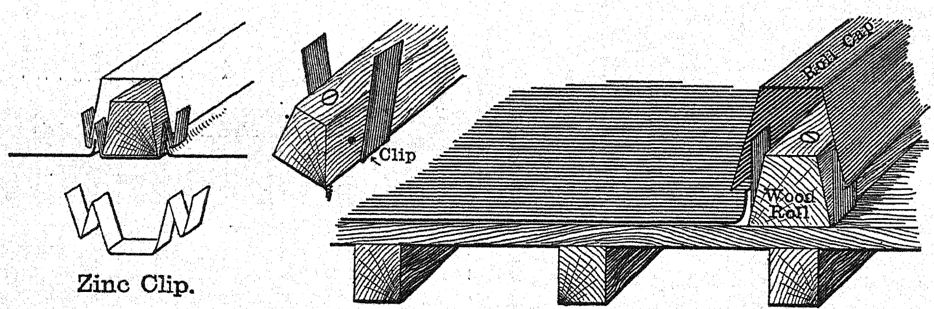


Fig. 72.

The next simplest roof is the "lean-to." This, as its name implies, leans against a wall, and is dependent on the strength of the wall for its security. Its most common use is for the smaller portions of a structure, although it may be used independently, as its alternative name of shed-roof indicates. Although good enough for small additions of moderate height, taking advantage of the lofty wall of the main building, it is not the best form of roof. When the inner side is to be ceiled with a level ceiling it is improved, because the ceiling joists can be nailed or bolted to the rafters (Fig. 73). It can be improved again by uprights fixed to one or more of the rafters and ceiling joists, thereby making a triangular frame (Fig. 74). Still further it may receive a strut or brace and, if necessary, an iron tie (Fig. 75), which

is about as far as a lean-to roof needs to be developed. This last improvement, it will be seen, converts the frame into a series of three triangles, and the rafter so supported is not likely to bend with the weight of the covering.

The span-roof is developed on the same principles, and in its simplest form consists of rafters, wall-plates, ridge-purlins, and collar-beam or tie-beam. It is possible to substitute iron rods for these last (Figs. 76 to 81). It would aid the beginner to understand the principles of roof construction if he considers where a rope might be used instead of a beam. There are in buildings three strains that can be brought upon the timbers—compression, as in the case of storey-posts or posts bearing weight; tension, as in the case of tie-beams or king-posts; cross strain, as in the case of joists, rafters, purlins, floor-boards, etc.

In modern practice it is not often that timber is exposed to compression, though the resistance which wood gives to a direct load is enormous. Authorities state that breakage, when it does occur, is preceded by bending, so that the point of vital importance, in timbers sustaining heavy weights, is to guard against bending, then their safety is ensured. As to tension, it is calculated that oak or fir of 1 inch square section will break with a load of $5\frac{1}{8}$ tons and $5\frac{1}{4}$ tons respectively, so that it is practically impossible to tear asunder a piece of even moderate size by a tensile force applied in the direction of the fibres; hence the dimensions of tie-beams, king-posts, and any other timbers that are subjected to tension, depend upon the necessity of forming joints with other portions of the frames to which they belong. Such joints often depend upon lateral cohesion, which is not so considerable in many kinds of wood. It is for this reason that iron rods so often take the place of wood, because of the ease with which the rods can be united with the timbers, either by plates, sockets, or bolts and nuts. Frequently cast-iron sockets into which the feet of rafters are fixed are united by a wrought-iron rod, in lieu of a tie-beam (Fig. 81).

But cross strain is the most important, as well as most frequent, strain to which building timber is exposed. The strength of a beam is (1) as its width; that is, increase in width increases strength in the same proportion; (2) as the square of its depth, therefore doubling the depth makes resistance fourfold; (3) the strength is inversely as the length, so that a beam well supported in the centre becomes thereby twice as strong. In order to make this formula practical, tests have been made of pieces of wood of known dimensions, of various kinds, thereby to determine a "constant" for each wood. For this purpose the depth and breadth are to be expressed in inches, and the length in feet. On these conditions the number for deal or English oak is given as 400 lb. breaking strain, for beams supported at both ends and loaded in the middle. Example, a beam 9 inches × 3 inches × 12 feet long; what is the breaking strain?

$$\frac{400 \times 3 \times 9 \times 9}{12} = 8{,}100 \text{ lb.}$$

Supposing, however, that the beam were laid so as to be 9 inches wide and 3 inches deep, then

$$\frac{400 \times 9 \times 3 \times 3}{12} = 2{,}700 \text{ lb.}$$

It is generally accepted that a beam will bear about twice the load if uniformly distributed. On the other hand, not more than a quarter of the breaking load ought to be put upon any timber, or injury will be done to it. A practical test of a finished building is to measure the deflection under a load, and if the bending is sensible, under average conditions, such part of a building must be strengthened. The angle which the sides of a roof make with a horizontal line varies according to the style of architecture and the intended covering. Tiles require a higher roof than slate, while the metal coverings may be flatter. It is, however, only important for the carpenter to know the weight of the covering and the angle, in order to provide timber strong enough for the purpose.

The Gothic roof is either based upon an equilateral triangle, or an angle approaching it, and as such roofs are often timbered, tie-beams would be a serious obstacle. The walls, however, of Gothic structures have buttresses outside, in order to resist the outward pressure of the roof timbers, besides which, by an added portion, contributing much to the ornamental appearance of these roofs, much of the weight is transferred to a lower level of the wall (Fig. 82). The sketch shows that the same principle applies to these roofs as to all others—the rigidity of the triangle.

Hip-roofs are so called when the walls are not carried up to the ridge of the roof, but the roof itself is formed of inclined planes meeting each other at the "hips." As the wall-plate, on which the rafters rest, should be horizontal, and the summit or highest line of the roof would offend the eye if it were inclined to the horizon, buildings having unequal angles on plan require a flat instead of a ridge, generally, however, of small area.

The figure will show a simple mode of developing the areas of hip-roofs. The arcs are drawn merely to indicate the sources of the various lines. It would greatly assist the young carpenter to understand these rather difficult subjects if he would

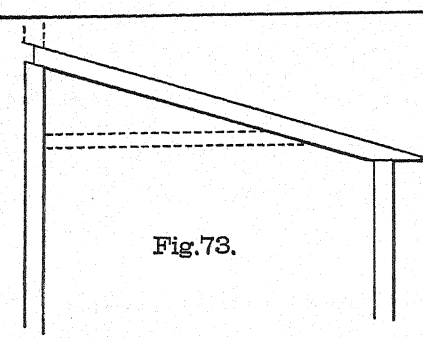


Fig.73.

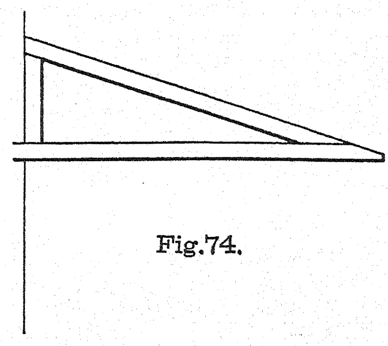


Fig.74.

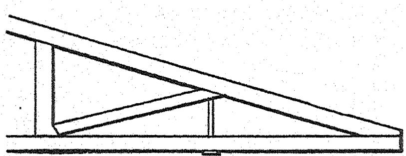


Fig.75.

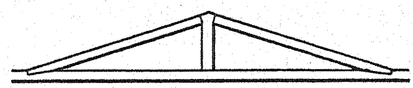


Fig.76.

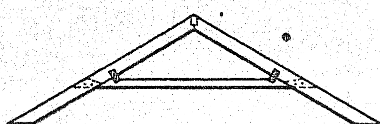


Fig.77.

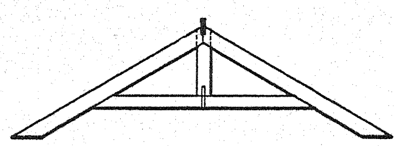


Fig.78.

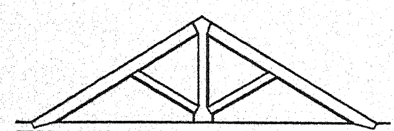


Fig.79.

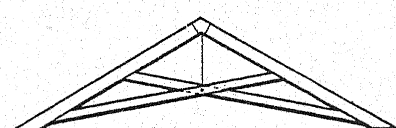


Fig.80.

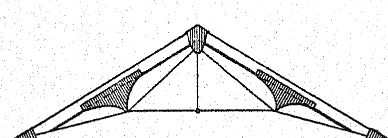


Fig.81.

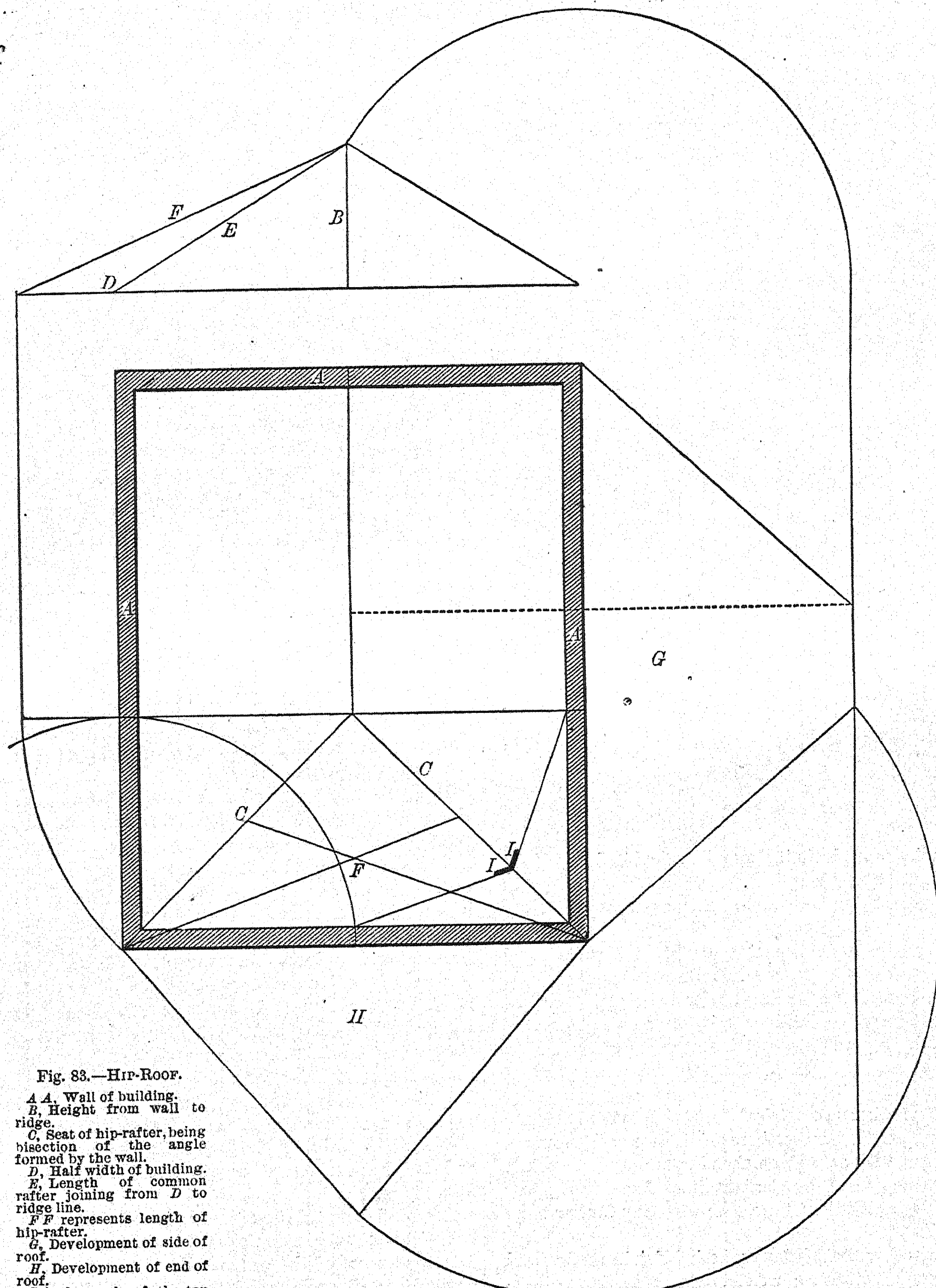


Fig. 83.—Hip-Roof.

A A, Wall of building.
B, Height from wall to ridge.
C, Seat of hip-rafter, being bisection of the angle formed by the wall.
D, Half width of building.
E, Length of common rafter joining from *D* to ridge line.
F F represents length of hip-rafter.
G, Development of side of roof.
H, Development of end of roof.
I is the angle of the top of hip-rafter.

study the subject of orthographic projection, and make a cardboard model, or better still, a wooden model of a hip-roof.

In the figure the angle of the upper surface of hip-rafter is shown at I. The rest of the figure will be best understood by regarding G and H as folded over to meet each other, and representing the surfaces of the roof. From these the lengths and

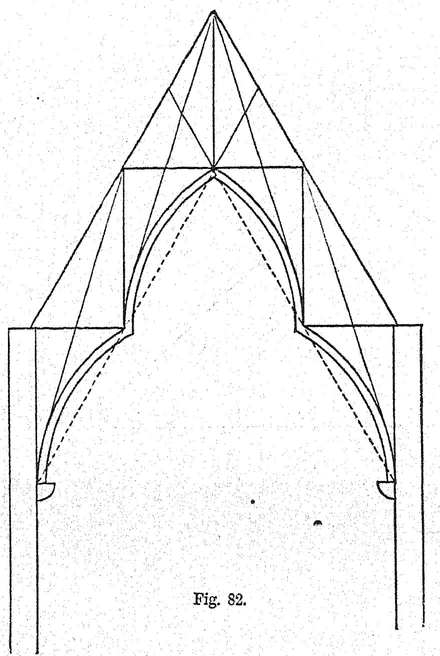


Fig. 82.

angles of each timber may be calculated, and if the scale adopted is $1\frac{1}{2}$ inch to the foot, one-eighth will represent 1 inch, and an ordinary rule will serve every useful purpose.

The young carpenter ought to realise and remember that the circle drawn touching F, in order to obtain the angle I for backing hip-rafters, is so drawn to obtain a point on C at right angles to the hip when erected, for every tangent is at right angles to a radius drawn from the point of contact.

The other geometrical fact of great importance in roofing is, that any three points near or distant may be regarded as a plane, that is, that any three points may be joined by straight lines forming a *plane* triangle; this is not the case with any four or more points.

Another fact that may be helpful in roofing and other constructive work is that a semicircle contains a right angle.

It is not too much to assert that the understanding of roof angles, oblique joints, and setting out curved work, is in proportion to the understanding of right-angled triangles, so that no study of this subject by an intelligent workman can be in vain.

PRACTICAL MECHANICS.—VI.

By R. Gordon Blaine, M.E.

Assoc. M. Inst. C. E., &c.; Senior Demonstrator and Lecturer on Mechanical Engineering and Applied Mechanics at the City and Guilds of London Technical College, Finsbury.

[*Continued from p.* 317.]

HYDRAULIC MACHINES.

HYDRAULIC CRANE.

The hydraulic crane is much used about docks and in warehouses. A small machine of this kind, such as that used at large railway stations, is shown in Fig. 40. It will be seen that the ram is in the centre of the crane-post, and, as it is forced out by the pressure-water from the hydraulic mains, it pulls in the chain from which the load to be raised is suspended. There is one fixed and two movable pulleys hence, as explained in the last lesson, the mechanical advantage is 4 to 1. The ram employed for "slewing" is seen in the base of the machine. Larger cranes, such as those used at docks, have usually a higher velocity ratio than 4 to 1.

HYDRAULIC MACHINE TOOLS.

Hydraulic power is now largely employed in connection with machine tools. I shall refer only to one or two of these.

In Fig. 41 is seen a reduced view of an immense riveting machine, designed by Mr. R. H. Tweddell, M.I.C.E., of Westminster, who has done so much to introduce and perfect hydraulic machine tools. The ram of this machine has a die attached to it, and when the ram is forced out the die forms the rivet which is under it, at the same time exerting a great pressure on the plates to be riveted. This machine can exert the immense pressure of 200 tons. A small portable riveter is shown in Fig. 42 at work on the keel of a ship which is in course of construction, whilst Fig. 43 shows an hydraulic punching and shearing machine, by which holes are punched in plates to receive rivets, or the plates are shorn much in the same way as one cuts cloth with scissors.

The principle in all these machines is the same, and is given in our description and elementary figure (Fig. 34).

The whole area of the cross-section of the ram of one of these machines in square inches, multiplied by the pressure of the water in lb. per square inch, gives the total force exerted by the ram; and if this is applied to the comparatively small area of a steel

punch, the punch may be forced through plates of wrought-iron or steel sometimes one inch or more in thickness. A somewhat similar thing occurs when

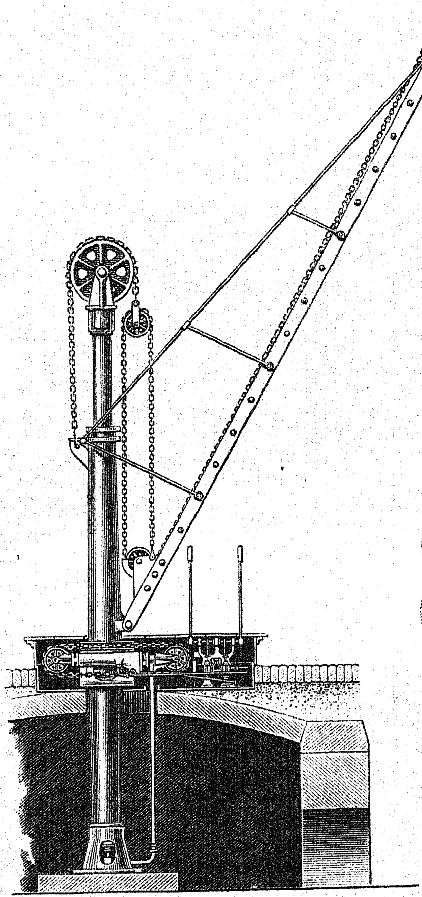


Fig. 40.

the upper blade of the shears is forced down by the egress of the ram attached to it from its press. The inlet and exhaust valves for admitting and releasing the water are worked by hand or foot, and the stroke of each ram can be adjusted to a nicety by tappet motions.

It is in the directions to which I have briefly referred that hydraulic power has been most successful, *i.e.*, where a slow, steady stroke and great pressures are required. Rapid motions, especially if reciprocating, do not so readily admit of being produced by pressure-water. There are, however, some fairly successful examples of engines driven by water instead of steam.

WATER-PRESSURE ENGINES.

The action of one of these engines will be understood from an examination of Fig. 44, which shows

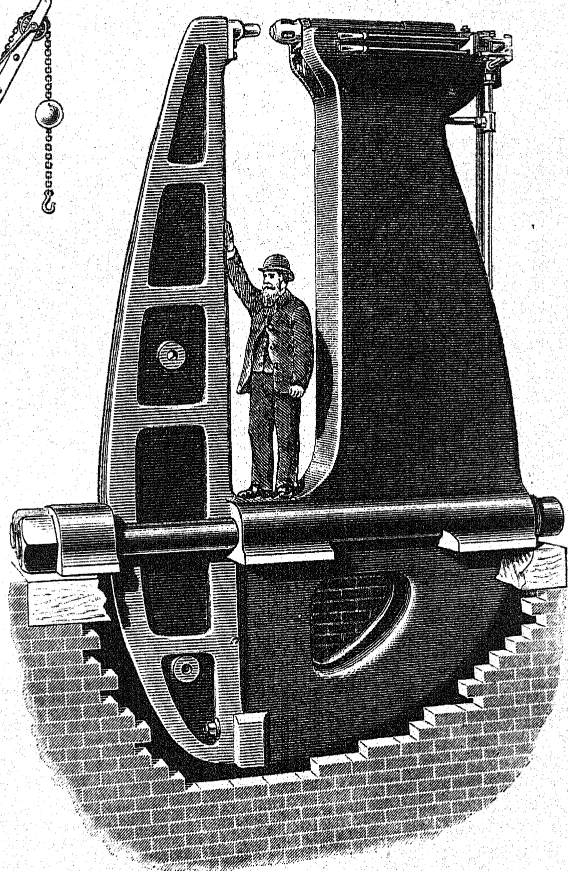


Fig. 41.

a horizontal section of the machine. Pressure-water is admitted by the valves, V, and drives forward each piston, P, in succession, thus giving a rotary motion to the crank-shaft, the centre of which is at O, the centre of the crank-pin being at R; hence O R is the length of the crank and twice this the length of the stroke of each piston. By a suitable valve the water is allowed to exhaust in the back-stroke of each piston, the engine being single-acting.

It will be noticed that the pistons are of the kind known as "trunk" pistons; in other words, the piston-rod, D, is the connecting-rod, and can oscillate about the pin, N, thus giving compactness to

the machine. If the speed of the engine is not too great, it works very well.

One defect in all hydraulic machines is that they require the same amount of pressure-water (*i.e.*, the same number of foot-pounds of energy) for one stroke, whether the machine is working fully loaded or only with a very small load. Now, as every gallon or cubic foot of this water costs a certain amount, it evidently costs as much to lift the empty cage of a hoist as the largest load it is capable of raising.

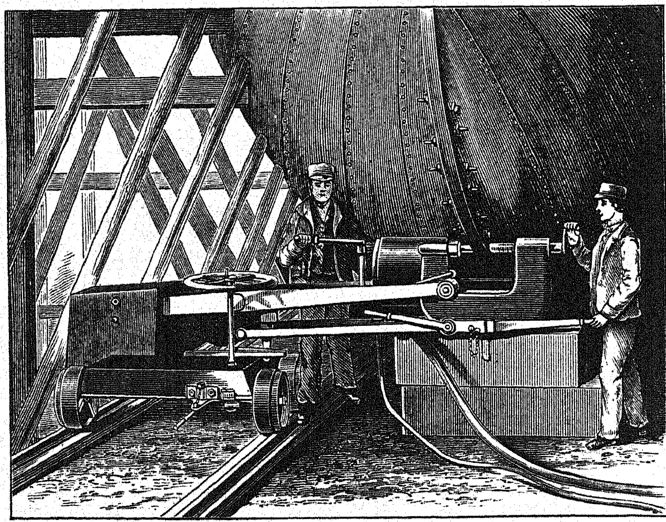


Fig. 42.

In the case of the engine shown in Fig. 44, the same reasoning holds; for it is not possible to cut off the water before the end of the stroke, and then obtain more work from it by expansion, as in the case of steam in the cylinder of a steam-engine. Various contrivances have been brought out to obviate this difficulty, with only partial success. It is sufficient for me, however, to mention the fact in passing.

USEFUL RULES.

In closing this lesson, I wish to refer to a great fundamental law which enables us to make calculations about water flowing under pressure. It is as follows:—The total energy

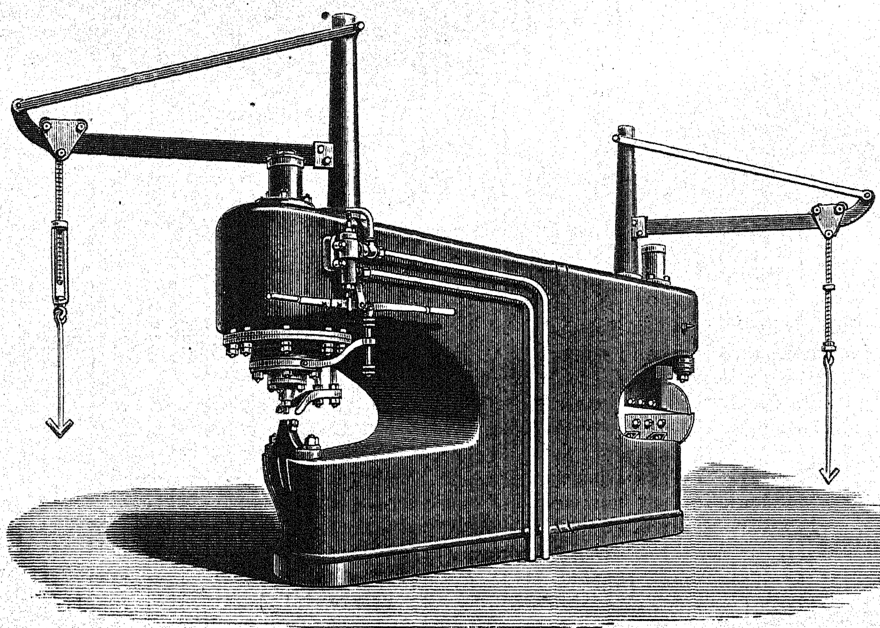


Fig. 43.

of 1 lb. of water moving along "lines of flow" is given by the expression—

$$h + \frac{v^2}{2g} + 2{\cdot}3p,$$

and this is constant if we neglect friction. In this expression h is the height of the water above an

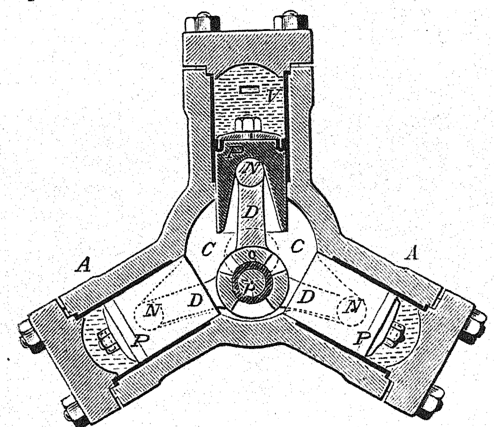


Fig. 44.

assigned datum level, v its velocity in feet per second, and p its pressure in pounds per square inch. No matter how these terms may vary separately, their sum is constant. In hydraulic mains in a city like London the first term is negligible, as differences of level are unimportant; the velocity of the water also is, or ought to be, small: hence the energy of the 1 lb. of water is mainly found from the last term of the expression.

From this you can easily calculate how much energy (or, if you know the rate of flow, how much power)* a man receives when he receives a given number of gallons of water at a stated pressure. Also, from this rule and certain experimental data given by D'Arcy and others, we can obtain an expression for the approximate *waste* of power in passing along hydraulic mains of given diameter. Such a rule as the following is very useful:—

$$\text{W} = {\cdot}00374\,\frac{\text{LE}^3}{p^3 d^5},\dagger$$

where W is the horse-power wasted in L feet of straight pipe, d feet in diameter, the pressure per square inch being p lb., and E the horse-power sent into the pipe. It is evident from this that it is very important—so far as consistent with extra cost, etc.—to have large pipes, and also to have high pressures. In electric transmission of power a somewhat similar question occurs.

* The term "power," as here used, will be fully explained in the next lesson.

† *See* article on "Hydraulic and Electric Transmission of Power" by the writer, published in *Engineering* of May 22 and June 5, 1891.

ELECTRICAL ENGINEERING.—VI.

By Edward A. O'Keeffe, B.E.,
Senior Demonstrator in Electrical Engineering, City and Guilds of London Technical College, Finsbury.

[*Continued from p.* 321.]

THE DYNAMO (*continued*).

THE MAGNETIC CIRCUIT (*continued*).

The following tables of observations made by Hopkinson are instructive, as they refer to the two kinds of iron used in the construction of the Edison-Hopkinson dynamo:—

Hopkinson on Annealed Wrought-Iron.

H.	B.	μ.
2·	5,000	3,000
4·	9,000	2,250
5·	10,000	2,000
6·5	11,000	1,692
8·5	12,000	1,412
12·	13,000	1,083
17·	14,000	823
28·5	15,000	526
52·	16,000	308
105·	17,000	161
200·	18,000	90
350·	19,000	54

Hopkinson on Grey Cast-Iron.

H.	B.	μ.
5·	4,000	800
10·	5,000	500
21·5	6,000	279
42·	7,000	133
80·	8,000	100
127·	9,000	71
188·	10,000	53
292·	1,000	37

The third column, which is the permeability, is obtained by dividing the second by the first column, and represents the multiplying action which the iron has on the number of lines of force that would otherwise pass through the space. Looking at these figures it will be seen that, as the magnetising force increases, the amount of magnetism produced in the iron also increases, but not by any means proportionately; in other words, the permeability decreases as the magnetising force increases.

By plotting these figures on squared paper, as shown in Figs. 31 and 32, we can more clearly see what happens to the iron when subjected to gradually increasing magnetising forces. In the case of the wrought-iron, we see that for small

magnetising forces, up to about $H = 20$, the magnetic induction, or the number of lines sent through the iron, rises rapidly, and that when a $B = 15,000$

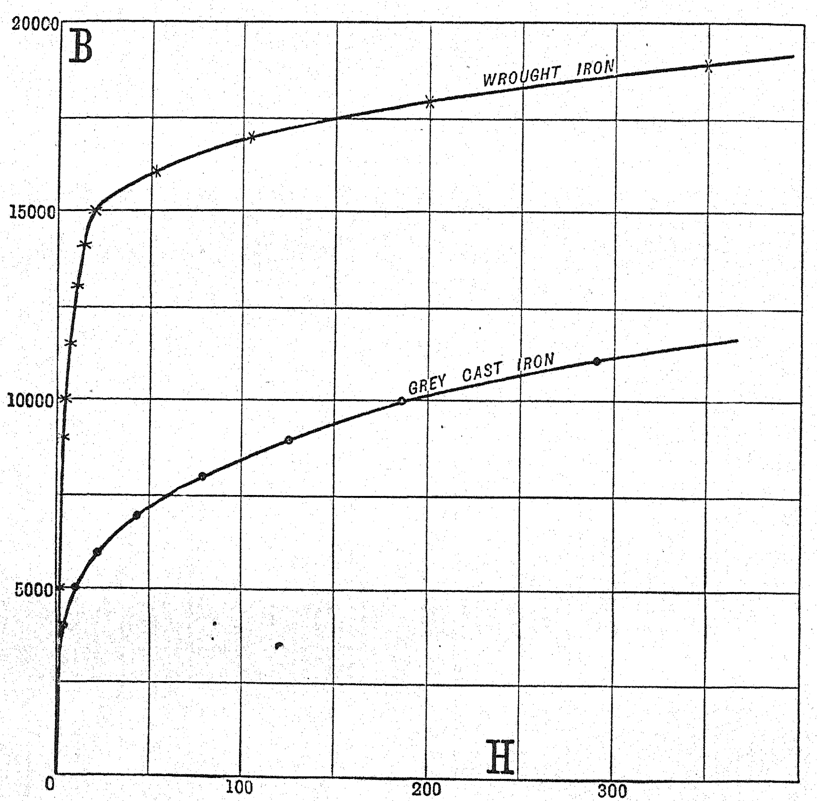


Fig. 31.—CURVES CONNECTING H AND B FOR WROUGHT- AND CAST-IRON.

lines per square centimetre is reached, it turns over and rises from this point onwards very slowly and almost along a straight line. This curve is called the magnetisation curve; for that particular quality of iron and the place where it turns over is known as the elbow of the curve. In the case of the grey cast-iron the character of the curve is different in many points; it still rises rapidly at the beginning, but reaches the elbow with a B of about 5,000 lines per square centimetre; the elbow is much longer than in the case of wrought-iron, extending from an $H = 5$ to an $H = 100$, after which point it slowly rises, as was the case with the wrought-iron. The highest degree of magnetisation that we can obtain in the case of the cast-iron with an $H = 300$ is 11,000 lines per square centimetre; whereas the same rate of induction can be obtained in wrought-iron with an $H = 8$.

In Fig. 32 we see the manner in which the permeability μ changes for different rates of induction through the iron. Within the limits here shown the permeability falls with increasing rates of induction. In the beginning this fall is not rapid, in intermediate stages it falls rapidly and almost along a straight line, and for still higher rates it falls to an extremely small value, and then turns almost horizontal. It will further be noticed that, for moderate rates of induction, how very much superior wrought- is to cast-iron.

The exciting force in any electro-magnet is derived from current circulating in the coils, and is proportional to the strength of that current and to the number of turns of wire on the coil. This force—which might be called the *magnetomotive force*, or the force tending to drive magnetism through the core—is usually measured in *ampere-turns;* an ampere-turn meaning a current of 1 ampere circulating once round the core, or $\frac{1}{10}$th of an ampere circulating 10 times round the core, or $\frac{1}{100}$th of an

ampere circulating 100 times round the core, etc. It can be expressed numerically thus :—

$$\text{Magnetomotive force} = \frac{4\pi s c}{10},$$

where c = current in amperes,
„ s = number of turns of wire,
„ $\pi = 3{\cdot}1416$,

and the 10 in the denominator is used to reduce the absolute current to amperes.

The product of s and c is the number of ampere-turns.

The number of lines driven through any substance by this force can be determined by a law similar to that of Ohm's for the electric circuit; thus—

Ohm's law says that

$$\text{Current} = \frac{\text{electromotive force}}{\text{resistance}}$$

If instead of current we substitute *magnetic flux*, or number of lines passing through the circuit; for electromotive force, we substitute magnetomotive force; and for resistance the word reluctance, we may then write the LAW FOR THE MAGNETIC CIRCUIT thus :—

$$\text{Magnetic flux} = \frac{\text{magnetomotive force}}{\text{reluctance}}.$$

Given the current and the number of turns of wire we know the value of the magnetomotive force from the last expression, but the reluctance is usually of a more complicated description, depending as it does on the nature and dimensions of the substances through which the lines are obliged to pass. Here, again, the law is similar to that which governs a resistance; thus—

$$\text{The resistance of a conductor} = \frac{\text{length}}{\text{section}} \times \text{specific resistance},$$

and in the case of the magnetic circuit consisting of a single piece of iron,

$$\text{Reluctance} = \frac{\text{length}}{\text{section}} \times \text{specific reluctance}.$$

The specific reluctance is, however, an expression which is never used, but the same meaning is attached to the reciprocal of μ. The value for the reluctance thus becomes

$$\text{Reluctance} = \frac{l}{\mu A},$$

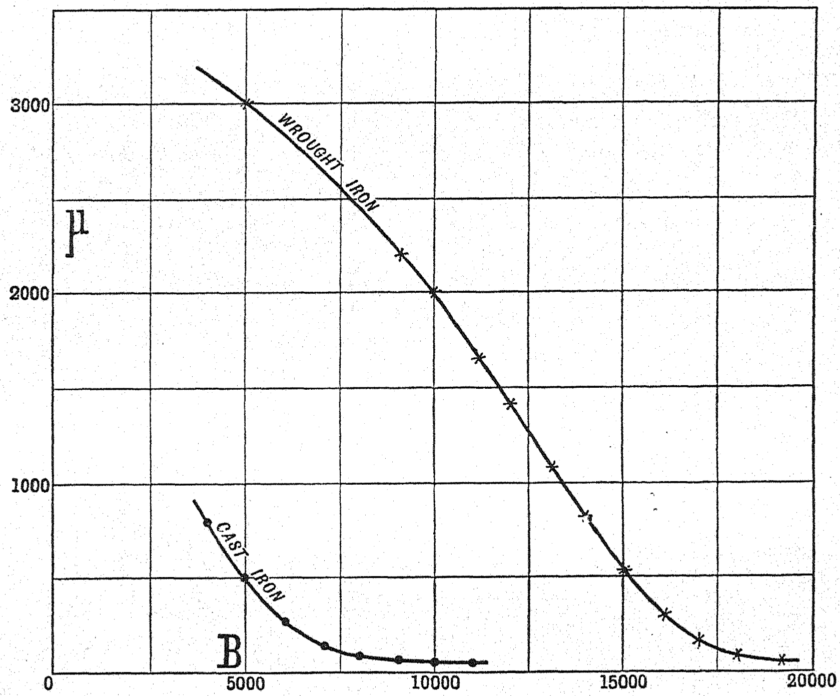


Fig. 32.—Curves connecting μ and B for Wrought- and Cast-Iron.

where l = the length in centimetres of the circuit through which the lines are forced,
A = the sectional area of the circuit in square centimetres,
μ = the permeability of the particular quality of iron for the given rate of induction.

(At the time of writing we have no unit in which to express the reluctance of any substance; its meaning may be best grasped by considering that it plays the same part in questions concerning the magnetic circuit that resistance does in the ordinary electric circuit.)

In the case of the magnetic circuit of the dynamo, the magnetic reluctance is composed of three distinct parts, namely:—(*a*) The iron of the field-magnets; (*b*) the air-gap separating the pole-pieces from the core of the armature (this also includes the winding on the armature, which has practically the same magnetic reluctance as air); and (*c*) the reluctance of the armature core. If we know the length and cross section of each of these parts and the number of ampere-turns that are wound on the magnets, we can find the number of lines available at the armature; thus,

$$N = \frac{4\pi S C}{10\left(\frac{l_1}{\mu_1 A_1} + 2\frac{l_2}{A_2} + \frac{l_3}{\mu_3 A_3}\right)}$$

where N = total number of lines,
,, l_1 = length of magnetic circuit of field-magnets,
,, A_1 = cross section of field-magnets,
,, μ_1 = permeability of field-magnets,
,, l_2 = length of air-gap (this clearly is doubled, since there must always be two air-gaps),
,, A_2 = cross section of air-gaps,
,, l_3 = length of magnetic circuit of armature core,
,, A_3 = cross section of armature core,
,, μ_3 = permeability of armature core.

Of this expression the part $\frac{4\pi}{10}$ is a constant equal to 1·257

$$\therefore \quad N = \frac{1{\cdot}257\, S C}{\frac{l_1}{\mu_1 A_1} + 2\frac{l_2}{A_2} + \frac{l_3}{\mu_3 A_3}}$$

In connection with dynamo design it more usually happens that we know the number of lines of force required to be sent round the circuit, and we then wish to calculate the number of ampere-turns which must be wound on the field-magnets in order to drive this number through the circuit. In this case—

$$S C = \frac{N}{1{\cdot}257}\left\{\frac{l_1}{\mu_1 A_1} + 2\frac{l_2}{A_2} + \frac{l_3}{\mu_3 A_3}\right\}$$

Of these three reluctances, that of the air-gap is considerably the greatest, and any diminution which this undergoes greatly improves the dynamo. For this reason the pole-pieces should embrace a large portion of the armature, and should be brought as near to it as mechanical considerations will allow. The necessity for iron as the core of the armature is now apparent; it serves as a path through which the lines of force can freely pass in going from one pole of the field-magnet to the other.

The ideal form of magnetic circuit is clearly a closed ring, but it is equally clear that this circuit cannot be employed in any dynamo. The aim of modern dynamo design is to make the magnetic circuit as nearly closed as is possible, having due regard to the clearance that must exist between the moving and fixed parts. There are necessarily two air-gaps in the magnetic circuit of every dynamo, the whole distance between the poles of the field-magnets and the core of the armature being reckoned as air-gap. The length of this air-gap should be made as short as possible, whilst its cross section should be made as large as possible. The field-magnets should be made as short and thick as they conveniently can, and should be composed of some substance having a high magnetic permeability, such as well-annealed soft wrought-iron. The circuit of the field-magnets should be as nearly as possible continuous, as any junctions in the iron interpose high magnetic reluctances to the passage of lines of force.

The goodness or badness of a dynamo clearly depends—other things being equal—upon the arrangement of the magnetic circuit and the quality of iron used. The magnetic properties of different samples of iron vary enormously, as may be seen from the curves in Figs. 31 and 32, and an intimate knowledge of the quality with which we are dealing is essential in order to design a dynamo. This knowledge must be obtained from experiments made on the samples, and such experiments may be carried out in the following manner:—

Ring Method.—A piece of the iron to be examined is made into the form of a ring of known diameter and known sectional area. This ring is overwound with a spiral of insulated copper wire sufficiently thick to carry the current without overheating. We must also be provided with the following pieces of apparatus:—

(*a*) A coil of wire—known as an *earth-coil*—wound in the shape of a ring, the average diameter of which is known, and also the number of turns.

(*b*) A battery capable of supplying the required currents,—where it is available an accumulator is most convenient for this purpose.

(c) A variable resistance.
(d) An amperemeter.
(e) A reversing switch.
(f) A ballistic galvanometer.
(g) Copper wires for making the connections.

These are connected up as shown in Fig. 33, which consists, as may be seen, of two complete circuits. One of these circuits contains the battery

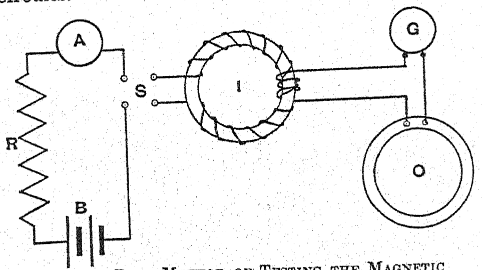


Fig. 33.—RING METHOD OF TESTING THE MAGNETIC PROPERTIES OF IRON.

B, the variable resistance R, the amperemeter A, the spiral of wire on the iron ring I, and the reversing switch S. The other circuit contains the earth-coil O, the ballistic galvanometer G, and a few turns of wire wound round the iron ring.

The experiments are carried out thus:—First, lay the earth-coil in a horizontal position and, when the galvanometer has come to rest, turn it right over so that its other face is now horizontal. By this operation all the lines of force due to the earth's field are taken out of one side of the coil and put into the other side; in other words, each turn of wire on the coil cuts the lines of force due to the earth's field twice during the movement. The cutting of these lines generates a quantity of electricity which flows through the galvanometer and produces a momentary deflection or "throw" on it. The amount of this throw is proportional to the number of turns of wire on the coil, to the area enclosed by each turn, and to the intensity of the earth's field at the place where the operation takes place. Expressed in symbols this may be stated thus—

$$d \propto n \times 2 \pi r^2 \times V \quad \ldots \quad \ldots \quad \ldots \quad (a),$$

where d = the amount of the throw,
" n = the number of turns on the earth-coil,
" r = the radius of the earth-coil (in centimetres),
" V = the intensity of the earth's field. This quantity is the vertical component of the earth's terrestrial magnetism, and varies slightly according to the locality in which the experiment is made. It is the number of lines of force that passes vertically through each square centimetre. Its value in London is about ·41.

The second observation consists in switching on the current, and when the galvanometer has come to rest, reversing its direction through the spiral on the ring by means of the reversing switch, at the same time noting the throw on the galvanometer corresponding to the reversal, and the current through A.

The throw now obtained is proportional to the number of lines of force passing through the iron ring, and to the number of turns of wire of the secondary or galvanometer circuit which encircle the ring.

Or
$$D \propto N A B \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (b),$$

where D = the throw on galvanometer,
" N = the number of turns of wire of the secondary circuit which encircle the ring,
" A = the sectional area of the iron in square centimetres,
" B = the number of lines of force passing through each square centimetre section of the iron.

Now dividing (b) by (a) we get

$$\frac{D}{d} = \frac{N}{n} \times \frac{A}{2 \pi r^2} \times \frac{B}{V},$$

or

$$B = V \frac{D}{d} \times \frac{n}{N} \times \frac{2 \pi r^2}{A} \quad \ldots \quad \ldots \quad \ldots \quad (I.).$$

We thus find the number of lines of force passing through each square centimetre of the iron ring corresponding to a known strength of current, and a known number of convolutions of wire on the primary circuit. In order to plot the magnetisation curve for the iron under test we must calculate the value of H corresponding to B from the formula—

$$H = \frac{4 \pi}{10} \frac{S C}{l} \quad \ldots \quad \ldots \quad \ldots \quad (II.),$$

where S = the number of turns on the primary circuit,
" C = the current flowing through the primary circuit,
" l = the length of the iron circuit, which is the mean circumference of the ring.

We thus obtain the values of B and H, which give us one point on the magnetisation curve of the iron under test corresponding to a given number of ampere-turns of excitation. This point should be plotted as shown on the curves in Fig. 31. The value of μ, corresponding to this value of B, is obtained by dividing the B by the H, thus:—

$$\mu = \frac{B}{H}.$$

This gives us the values for B and μ, from which one point of a curve similar to those in Fig. 32 can be plotted. In order to plot the complete curve it is necessary to obtain a large number of points, which means that a large number of observations with different strengths of current must be made. In carrying out these observations it is advisable to commence with the smallest current it is intended to use and to gradually increase it by varying the resistance R up to its highest value, taking a series of throws (D's) from which the values of B can be calculated. It is sufficient to take one throw (d) with the earth-coil, as its value does not change. Care must be taken that there is no iron or any other magnetic substance in the vicinity of the earth-coil when its throw is being obtained, as the value of V might thereby be changed.

This manner of testing the magnetic properties of a sample of iron is one of the best, but it is essentially a laboratory method.

CUTTING TOOLS.—VI.

By R. H. Smith,
Professor of Mechanical Engineering, Mason's College, Birmingham.

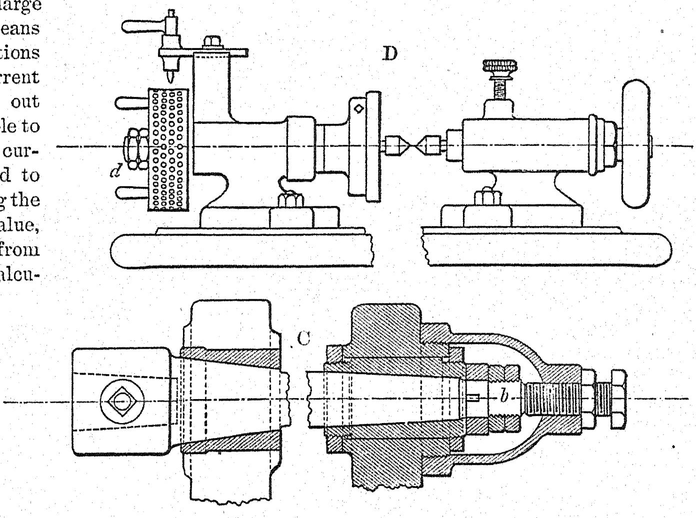
[*Continued from p. 280.*]

SAWS AND MILLING MACHINES (*continued*).

MILLING MACHINES.

Milling machines are analogous to the wood-planing machines, but differ from them in usually having the cutting tools, not inserted, but solid with the cutter-block. The cutter-block, or milling wheel, is simply a disc from 1 up to 16 inches in diameter, on the periphery of which are cut sharp teeth. Solid milling cutters have been made as large as 22 inches in diameter and $5\frac{1}{2}$ inches wide, this size being, however, very exceptional. If a plane surface has to be cut, the toothed surface of the milling wheel is cylindrical. If notches are to be cut to special forms, such as, for instance, the interspaces between the teeth of wheels, the contour of the axial section of the milling wheel is shaped accordingly, so as to fit exactly into the recesses to be cut out.

This sharp-toothed milling wheel is rapidly revolved and moved gradually from point to point over the whole surface that is to be operated upon. In order to bring the cutter successively over all the different portions of the work, two "feed"



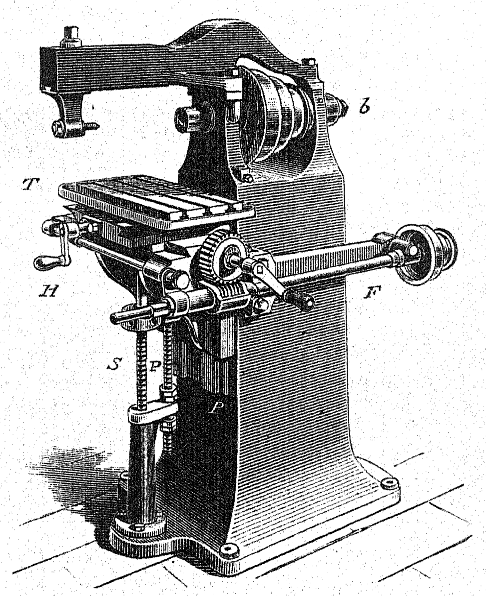


Fig. 18.

motions are necessary. Any shape of surface may be produced by a suitable combination of these feeds, and they may be combined in varying proportions by means of a "copying bar," or "former," the form of which corresponds to that desired in the finished work, and along which one bearing of

the cutter-spindle is made to slide. The machine is then often called a "profiling" machine.

Fig. 18 shows a milling machine for plane work. The spindle, upon which the cutter is fixed, has keyed on it a three-stepped cone. This is driven by a belt direct from the counter-shaft overhead. The spindle revolves in two conical main bearings (*see* detail drawing C of spindle). Beyond these is a "steady" bearing, supported by the cantilever bracket extending from the top of the frame, and longitudinally adjustable. The part of the spindle between the outer main bearing and the "steady" is detachable and interchangeable for different sizes of milling cutter. Its coned end fits in a conical

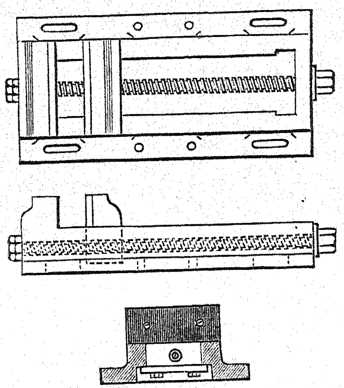


Fig. 19.

socket bored in the end of the main spindle. The early milling machines were made without the "steady," but its provision very greatly raises the standard of accuracy and high finish that can be given to the work, and it is, therefore, an almost invariable feature in the design of modern English-made machines. The axial thrust is supported at the flat adjustable bearing *b*, specially provided for the purpose at the back end of the spindle. The principal bearings are made conical to allow of the spindle being drawn back by the adjustable screwed collars after the brasses have worn. These bearings are placed in a headstock which is cast on the frame of the machine. The axis of the spindle, therefore, always occupies the same position.

The work is fastened firmly to the cast-iron table T. A very convenient appendage to such a table for small work is a machine vice, Fig. 19. This vice is bolted to the table, and the work fixed in it. This kind of table and machine vice is also used in exactly the same form in shaping machines to be hereafter described, and very similar ones are used in slotting and in drilling machines.

The table slides up and down on dove-tailed guide-surfaces on the vertical face of the plate P. It is raised and lowered by means of a nut and screwed spindle, S. This vertical motion is not one of the two feed-motions previously referred to. It is more properly a "setting" motion, whereby the work is brought (by hand) to the required height. If, however, the surface has to be gone over more than once, the table has to be raised between the cuts, and the amount by which it is so raised would be quite properly called "feed."

The upper part of the table T is fed horizontally parallel to the spindle upon V guides fashioned in the second part of the table. This first feed is operated by "hand" by turning the handle H which fits on the squared end of a horizontal screwed spindle having collar bearings in the second plate and passing through a nut fixed on the lower surface of the upper plate. The second, or "main" feed, or "traverse," is horizontal and transverse to the cutter spindle, and is obtained by a similar screw and nut connection between the second and third parts of the compound table. This second feed has to be operated continuously, and is, therefore, made automatic or "self-acting." A worm-wheel, mounted on the end of the feed-spindle, is driven by a worm keyed on the shaft F, which in its turn is driven by a belt on the cone-pulley at its hinder end. By running this belt on a smaller or larger cone step, a more or less rapid feed can be given to the work.

Much of the work done on milling machines is cylindrical, or prismatic, in general outline. First one small strip of the surface parallel to the axis of the cylinder or prism is milled, and then in succession, other exactly similar strips, at equal distances from the axis, are operated on. Such work is conveniently fixed on a mandrel or otherwise, and placed between centres accurately perpendicular to the cutter-spindle, such as are shown at D, Fig. 18. The traversing feed being put in motion, the cutter will plane off a surface parallel to the line of feed, and, therefore, if the centres have been carefully set, accurately parallel to the line of centres. Between each successive cut, the mandrel is revolved on the centres through any desired small or large angle. During each cut it must be firmly prevented from revolving. This may be simply managed by fastening a small toothed wheel on the mandrel, and arranging a spring-catch to wedge in between any pair of teeth corresponding to the desired position of the work on the mandrel. For instance, if the work to be done is cutting out the teeth of change, or other wheels, a wheel is fixed on the mandrel with either the same, double, treble, or any multiple of the number of teeth in the wheel to be cut. A more accurate method of obtaining the same division is

by fixing on the mandrel a "dividing plate." This is simply a flat plate with a number of small holes drilled in it, corresponding accurately to given aliquot parts of the circle, and into which holes fits a little peg-stop passing through a hole in the centre-bracket. If the desired division of the circle is very simple—for instance, if it is desired to divide it only into, say, 2, 3, 4, 6, 8, 12 parts—the holes are often placed in the cylindrical periphery of the dividing plate; but if the division desired is to be complicated, so that the necessary holes are very numerous, the holes are placed in its flat face, and for important work such a dividing plate should be made of hard gun-metal or of phosphor bronze, in order to minimise the wear of the holes by the frequent insertion of the stop. By arranging the holes on four or five concentric circles, sufficient room for them is obtained without making

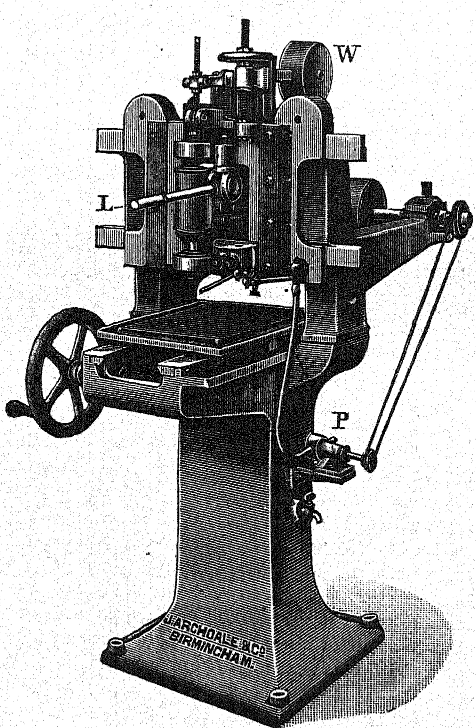


Fig. 20.

their diameter very small, and without making the dividing plate inconveniently large. A cylindric divider is shown at *d* at the left hand of D, Fig. 18.

Fig. 20 shows a "profiling" machine with vertical cutter-spindle. The spindle is mounted upon a vertically sliding carriage, but in this case the weight of this carriage is balanced by a balance weight, W, placed on the hinder end of a hori-

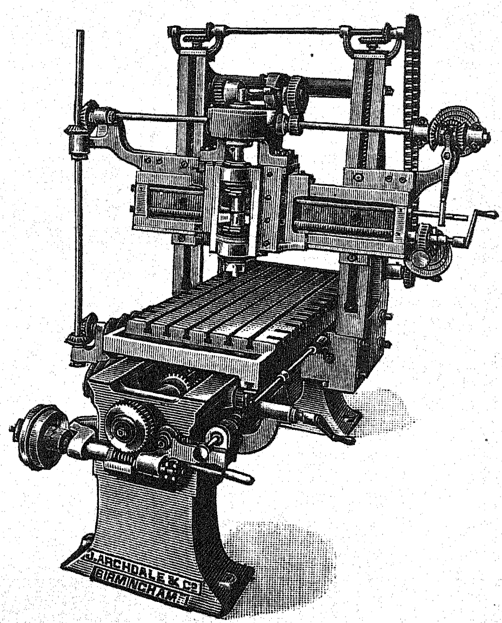


Fig. 21.

zontal lever, the front end of which is linked to the carriage. By means of the handled lever L, the whole can be raised or lowered with great ease. At the side of the machine may be seen the small rotary pump which raises the lubricating soap-and-water to the level of the cutter, whence it flows over the cut surface down into a collecting tank in the frame, to be once more pumped up and used over again.

Fig. 21 illustrates a powerful style of milling machine. The general arrangement of frame, table and feed motions, is similar to that of a planing machine such as will be described later on. The driving of the vertical cutter-spindle is by spur and bevel gearing mounted on the large cross-beam saddle. One feed is obtained by moving the table by a longitudinal feed screw lying underneath it, the other by moving the spindle-carriage across the large cross-beam. Both feeds are self-acting, and their range of motion is so great that the machine can cut large surfaces or parts of surfaces standing far apart, without shifting the clamping or "setting" of the work upon the table. These three machines are made by Archdale and Co.

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